

**TRANSPORT SYSTEM OF IMPORTED
LIQUEFIED NATURAL GAS IN VIETNAM
Case: PetroVietnam Gas Corporation**

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ABSTRACT

Natural Gas is an attractive energy alternative to oil. The demand for Natural Gas in Vietnam is thus dramatically increasing. By contrast, due to insufficient infrastructures, the indigenous supply cannot meet the demand. As a result, gas market players in Vietnam must look out for other sources of Natural Gas. In this context, Liquefied Natural Gas (LNG) import arises as an optimal solution.

The thesis is based on the real case of PetroVietnam Gas Corporation. Making a contribution to preparation studies of the LNG import, the thesis focuses on the transport system of LNG in Vietnam. The purpose is to identify a feasible solution to the transport system. Accordingly, foreign and expert partners are encouraged to invest in and supply to the LNG project. The issues under study are building up and running an LNG receiving terminal as well as transporting LNG to end users.

The study is performed based on the mix of qualitative and quantitative approaches but is primarily qualitative. The data for conducting the study are collected from primary sources like observation, interviews, company reports and secondary sources like books, articles and earlier researches.

The empirical part consists of a system analysis framework applied to site selection of the LNG receiving terminal. The preferred site for building up the terminal is decided based on its superior condition and economic validation. This site selection assists development of the layout and the operations at the terminal. With the receiving terminal in place, transportation to end users is accordingly determined. Owing to diverse demand of different customers, variation is shown in selecting transport modes, routing and scheduling. Besides, an activity analysis is undertaken to set performance measures for individual activities within the scope of the transport system.

To conclude, implications of the findings and recommendations are given. In most cases, decisions are made based on relative factors. Hence, to evaluate the trade-offs, costs and even public issues must be carefully considered. To make the LNG project successful, it is necessary to have cooperation among stakeholders and integration of related activities. In addition, proper control and R&D are of great importance to the import of LNG.

Key words: LNG, Natural Gas, transport system, receiving terminal, Vietnam

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GLOSSARY

Auto-refrigerate	The process in which LNG is kept at its boiling point, so that any added heat is countered by energy lost from boil off.
Asphyxiant	A material capable of reducing the level of oxygen in the body to dangerous levels, below the normal level of around 19% which can lead to breathing difficulties, unconsciousness or even death
BBtud	Billion British thermal unit per day, see mmBtu for further definition
Bcf	Billion cubic feet
Bunker	The fuel used by ships
Carcinogenic	Of or pertaining to the property of cancer-causing of a substance
Cryogenic	Of or pertaining to the production or use of very low temperatures
DES	Delivered Ex Ship (Incoterms 2000) means that the seller delivers when the goods are placed at the disposal of the buyer on board the ship not cleared for import at the named port of destination. The seller has to bear all the costs and risks involved in bringing the goods to the named port of destination before discharging.
Economies of scale	Cost reductions or productivity efficiencies achieved through size increases
Flammability range	The proportion of combustible gases in a mixture, between which limits this mixture is flammable

Flash point	The minimum temperature at which a liquid gives off a vapour within a test vessel in sufficient concentration to form an ignitable mixture with air near the surface of the liquid
FOB	Free on Board (Incoterms 2000) means that the seller delivers when the goods pass the ship's rail at the named port of shipment. This means that the buyer has to bear all costs and risks of loss of or damage to the goods from that point. The FOB term requires the seller to clear the goods for export.
Liquefaction	The process by which Natural Gas is converted into Liquefied Natural Gas
Maximum draft	For surface ships, the maximum navigational draft represents the greatest depth of the ship when it is fully loaded
MMBtu	Million British thermal units, which is a heating equivalent measure for Natural Gas, based on which prices typically quoted for Natural Gas are designated
MMcfd	Million cubic feet per day, a volume measurement of Natural Gas
Spatial structure	The manner in which space is organised by the cumulative locations of infrastructure, economic activities and their relations
Tanker	A ship, airplane, or truck designed for bulk shipment of liquids or gases
Transshipment	The transfer of goods from one carrier to another and /or from one mode to another
TWh	Terawatt hour, a measure of energy delivered by electric utilities

1 INTRODUCTION

1.1 Statement of the problem

In the keynote speech to the 7th Doha Natural Gas Conference and Exhibition, entitled “Natural Gas: A Cleaner Fuel for Tomorrow”, OPEC Secretary General, HE Abdalla Salem El-Badri, asserted that Natural Gas is becoming increasingly vital to the overall global energy mix. With its steady growth and a share of world energy supply that is forecast to reach nearly 25% by 2030, Natural Gas has very bright prospects. He explains the prospects of Natural Gas by recalling last year’s volatility in crude oil prices, in addition to the current economic downturn. Since Natural Gas complements oil, considering the challenges faced by crude will help us consider the prospects of the gas industry. (OPEC 9-12 March 2009.)

Natural Gas is drawing more and more attention recently and arising as an attractive alternative and sustainable energy to oil. Figure 1 represents Natural Gas production from 1987 to 2007. As can be seen in the figure, Natural Gas production increased steadily since 1987 till recent years, which indicates significant demands for this energy.

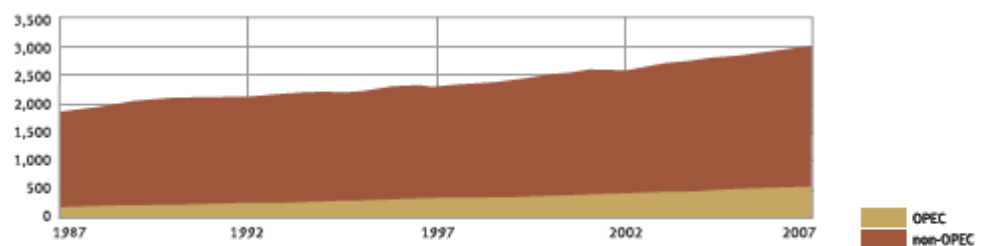


Figure 1 – World marketed Natural Gas production, 1987-2007 (*bn cu m*) (OPEC 2007, 65.)

It is a fact that while demand for Natural Gas is rising, some countries do not have access to sufficient amount of indigenous Natural Gas. Therefore, offshore Natural Gas supply appears as a proper solution to unmet demands. In order to transport Natural Gas in long hauls from one country to another, even half way around the world, sea-born transport of Liquefied Natural Gas (LNG) have been developed. It is foreseen for the world scenario in year 2020, LNG is to spread its

presence all over continents whereas there were merely 22 countries trading LNG in year 2000 (International Gas Union 2006a, 2-3.).

Working Committee Chairman of 22nd World Gas Conference, Angel Travasset (International Gas Union 2003a, 9.) forecasts in his report new LNG receiving terminals will be built in 2014, in accordance with the consumption of the LNG by several new countries and the increasing demand of some present consuming countries. It is estimated that their number would reach about sixty terminals, in which the LNG storage capacity will reach 24 million m³.

Imported LNG is used for as many purposes as indigenous Natural Gas. According to a report of industrial utilization and power generation, in many countries all over the world, industry and power generation offer important potential for future growth in gas consumption. In addition, increasing focus on environmental issues is promoting requirements to improve energy efficiency and reduce emissions. Demand for electricity continues to grow significantly throughout the world. As a result of increasing availability of gas supplies and combined cycle gas turbine technology developments, Natural Gas has been taking an increasing share of the power generation market. (International Gas Union 2003b, 4.)

In the picture of the LNG world trade, Vietnam is planning to import LNG. Currently Vietnam is short of power generation capacity, which is therefore slowing down the pace of economic growth. The removal of these constraints along with addressing security of fuel supply is at the forefront of Vietnam's energy policy. The growth is expected to be met by a combination of indigenous and imported coal, hydro and gas resources. The scale of growth required means that state-owned companies, even when including key energy market players Vietnam Electricity (EVN), Vietnam National Coal-Mineral Industries Group (Vinacomin) and PetroVietnam (PVN), are unlikely to be able to finance the power capacity and infrastructure build that is required in coming years.

The LNG import project is driven by the need to attract overseas supply and investment to fund the expansion of the Vietnam power generation sector. To implement this, an overall planning covering all aspects of the LNG import project is prerequisite. This concerns transportation, pricing, economic order

quantity, project finance, project economics, finding partners and suppliers as well as other supporting studies. With the initial understanding of LNG trading, the next subparts will provide clearer details of the project and the contribution of this thesis to it.

1.2 Objective

The aim of this study is to analyse a potential scenario of LNG import in Vietnam in terms of transport systems. The purpose is to encourage foreign investment and LNG supply.

Vietnam has been relying on indigenous coal, hydro and gas as its main sources of power generation. However, each of these fuel options has its limitations and the government is against dependency on any one of the three. Based on the most recent Power Development Plan (PDP6), Vietnam's authorities have expressed an anticipated country-wide generation capacity requirement of 111 GW by 2020 (EVN 2007.). With reserves and exploitation of above sources being limited and rapid industrialization in the country, in the near term the key challenge for the sector will be to develop adequate infrastructures as well as sourcing reliable fuel supplies to meet this goal. Besides Liquefied Petroleum Gas (LPG), Compressed Natural Gas (CNG) and others, LNG is considered to be developed within the energy portfolio of Vietnam. This consideration is due to the diversification of energies and the tremendous pollution problem in the country. The environmental friendliness of LNG makes it a prospective alternative to traditional energy sources in Vietnam.

Seizing the essence of LNG, PetroVietnam Gas Corporation has started to analyse the LNG import scenario, deal with issues in relation to establishment of an LNG import terminal and the role of different modal transportation in an LNG project. Moreover, to employ the LNG import, the company enters into a rivalry with another company. It is a fact that the shortage of the Vietnam energy market is of a specific amount. As a consequence, once an LNG project is launched, there is no room left for the others. In other words, two or more LNG projects are superfluous. To be the first in the market, then, is prerequisite.

The thesis is based on the real case of PetroVietnam Gas Corporation. Because of great investment of money as well as technologies that an LNG import project requires, the company is willing to cooperate with foreign partners who have expertise in LNG. To attract cooperation, analyses are to be achieved in order to pinpoint potential of the LNG import scenario. This thesis takes into consideration analyses with regard to establishing an LNG receiving terminal and accordingly planning a transport system of LNG in Vietnam.

1.3 Research methodology

According to Kumar (2005, 6.), there are several ways of obtaining answers to professional questions and research is one of the ways to find answers to our questions. For this reason, this part aims to clarify the research methodology that the writer employs. With reference to research, there are several perspectives, either mutually exclusive or not. In the following paragraphs, study design, research approach, research method and method of data collection are discussed.

First and foremost, the thesis is designed as a case study. The case study method investigates a social phenomenon through a thorough analysis of an individual case. All data relevant to the case are gathered and organised in terms of the case. It provides an opportunity for the intensive analysis of many specific details often overlooked by other methods. (Kumar 2005, 113.)

Next, research approach defines the way in which the research is developed. In deductive approach, a theory or hypothesis is developed first, and then a research strategy is designed to test the hypothesis. On the contrary, in inductive approach, data are collected and analysed to produce the theory. (Saunders, Lewis & Thronhill 2003, 85.) In this case study, inductive approach is applied.

Afterward, before going further to the choice of either qualitative or quantitative methods, their definitions are reviewed. Cooper and Schindler (2008, 162) think qualitative research includes an array of interpretative techniques which seek to describe, decode, translate and otherwise come to terms with the meaning, not the frequency of certain more or less naturally occurring phenomena in the social world. On the other hand, quantitative research is used to quantify the variation in a phenomenon, situation, problem or issue (Kumar 2005, 12.).

Despite the differences between qualitative and quantitative methodologies, Padgett (1998, 2.) points out that many researchers transform qualitative data into numerical data. Cooper and Schindler (2008, 185-186.) advocate their mergence to increase the perceived quality of the research. A quantitative study may follow a qualitative one to provide validation for the qualitative findings. Creswell (2003.), Axinn and Pearce (2006.) and Mertens (2004.) highly appreciate the use of the mixed method of qualitative and quantitative which can mutually supplement each other.

The thesis is written based on the mix of qualitative and quantitative methods. Even though, qualitative method takes priority to quantitative. As introduced in the related subheading, a system analysis framework is applied. A framework is a qualitative view of a complex system, as it is not necessarily numerically, but in an organised form. (Sussman 2000, 128-129.) The framework is detailed in chapter 5 in concern with establishing an LNG receiving terminal. As to this specific analysis of the terminal, quantitative method complements qualitative one in a way that impacts of building the LNG receiving terminal in different locations are transformed into numerical data in order to measure location performance. Under the same heading, another framework is applied for the activity analysis. Furthermore, a SWOT analysis is used as a tool for the situation analysis.

Last but not least, the employed methods of data collection are mentioned as an implement tool for qualitative and quantitative approaches. With respect to the case, necessary data can be tracked from the two main sources among which primary data are collected throughout the practical training of the writer:

- Theoretical framework:

Primary data: observation, company reports

Secondary data: books, journals, articles

- Empirical part:

Primary data: interviews with the company's seniors who supervise the LNG import project, company reports

Secondary data: journals, articles, earlier researches

To summarize, a figure of the research process is created as follows:

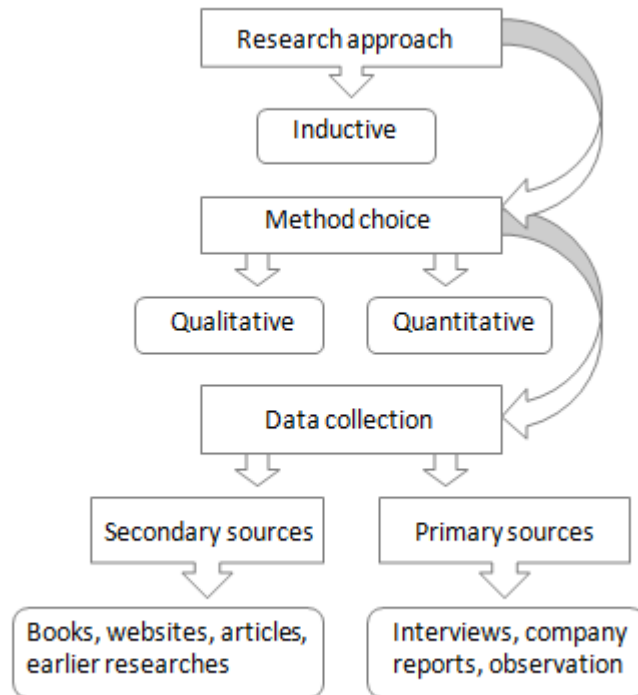


Figure 2 – Research process

1.4 Case study

The project of LNG import is under the responsibility of Import Development Department which was newly established by PetroVietnam Gas Corporation (PV Gas) for fulfilling demand for gas of the domestic market. The objective is to make LNG a common source of energy in the Vietnam energy market. The project sets targets to bring LNG into use from 2013 with 1 million tons and by 2025 with 10 million tons (PV Gas 2009a.).

PV Gas is a one-member limited company belonging to the parent company, PetroVietnam Group. PV Gas was established in October 1990 with a small staff of 100 employees. Nowadays, the company has become a powerful company with more than 1,050 employees. (PV Gas 2009a.) The organisation of PV Gas, excluding branches, subsidiaries and joint ventures, is comprised of 13 departments, with the board of directors which controls a complex operation of gas trading (PV Gas 2009b.).

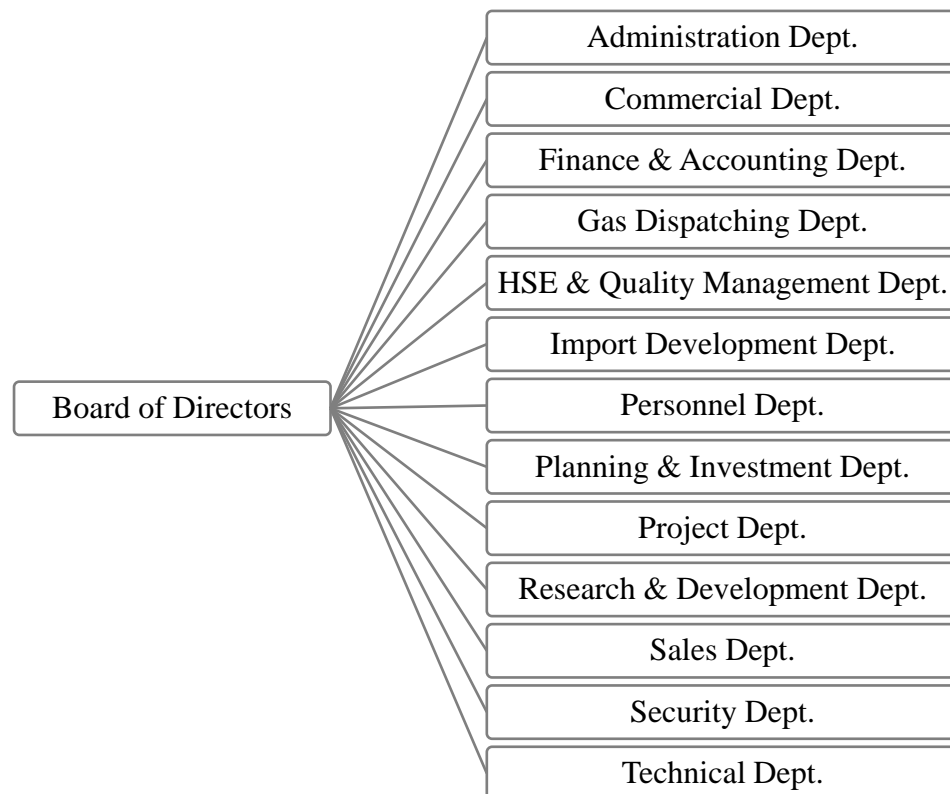


Figure 3 – Organisational chart of PetroVietnam Gas Corporation (PV Gas 2009b.)

Gas midstream and retail are the principle activities of the company. It is operating in transporting, storing, processing and marketing gas products and services. The main products and services are Processed Gas, Liquefied Petroleum Gas (LPG) and Condensate. PV Gas currently supplies Processed Gas and LPG to power plants, commercial and residential households, industrial zones like fertilizer, construction material plants, in addition, uses Condensate to produce gasoline. (PV Gas 2009a.)

1.5 Scope and limitations

First of all, it is necessary to identify that this case study conducts analyses focusing on the transport system in Vietnam of the LNG import project. In a particular scope of the whole transport system, this study only focuses on the latter leg of the transport system when LNG has been imported into Vietnam. However, in reality, export and import activities are in a mutual relationship. In general scope of the complete project, other studies need to be made in regard

with pricing, economic order quantity, project finance, project economics, finding partners and suppliers as well as other supporting studies, among which some are under analysis and the others are to be investigated. It is the case that within this thesis, the writer just puts emphasis on the transport system in Vietnam. As a consequence, some of relevant information provided by the company is taken for granted.

The study concedes that power generation section in general is the biggest energy consumer, and in specific, counts for approximately 75-80% of the demand for gas in Vietnam. Accordingly, the target of the LNG import project is power plants and the aim is to supply sufficient amount of gas.

In addition, as the thesis deals with LNG, a chemical product, project planning must encounter many technologies and procedures regarding processing and preserving. With the nature of a business study, the thesis to some extent simplifies this angle and explains as clear as possible given that business operations themselves cannot ignore technical issues.

Lastly, as unlimited resources are not available and this is primarily an academic thesis, the writer might have to do less than an ideal job. Here, the research question strives to answer logistical details, whereas availability of data barely allows case study designed mainly with qualitative methodology. The intuitive nature of a principally qualitative study may affect the validity of the writer's conclusions and generalisations.

1.6 Thesis structure

The thesis structure is comprised of two parts: theoretical framework and empirical part. Foremost, the thesis starts with chapter 2 – general introduction of LNG, subdivided into the first part about its original form, Natural Gas and the other part about LNG itself. This chapter gives a clearer description of the product that the study handles. From chapter 3 onward is the principle study focusing on transport system development of imported LNG in Vietnam.

The study formulates a transport system based on transport system theory. This theory covers main issues related to transport systems as reviewed in chapter 3, including frameworks of transport system analyses. Chapter 4 frames a current

situation analysis. The purpose of this situation analysis is not only for denoting a brief understanding of the project's potential but also indicating the influence of external components on the transport system itself. Chapter 5 performs an analysis of construction and operations of an LNG receiving terminal which acts as the key node complementing development of the whole transport system with transport modes and links. In chapter 6, modal choices and operations are under analysis. Along with infrastructures and operations, chapter 7 provides cost and performance measurement. Chapter 8 concludes the findings from all afore discussed issues. Last but not least, chapter 9 finishes off the thesis with a summary.

The following figure illustrates the thesis structure, with note that numbers attached with some titles indicating chapters.

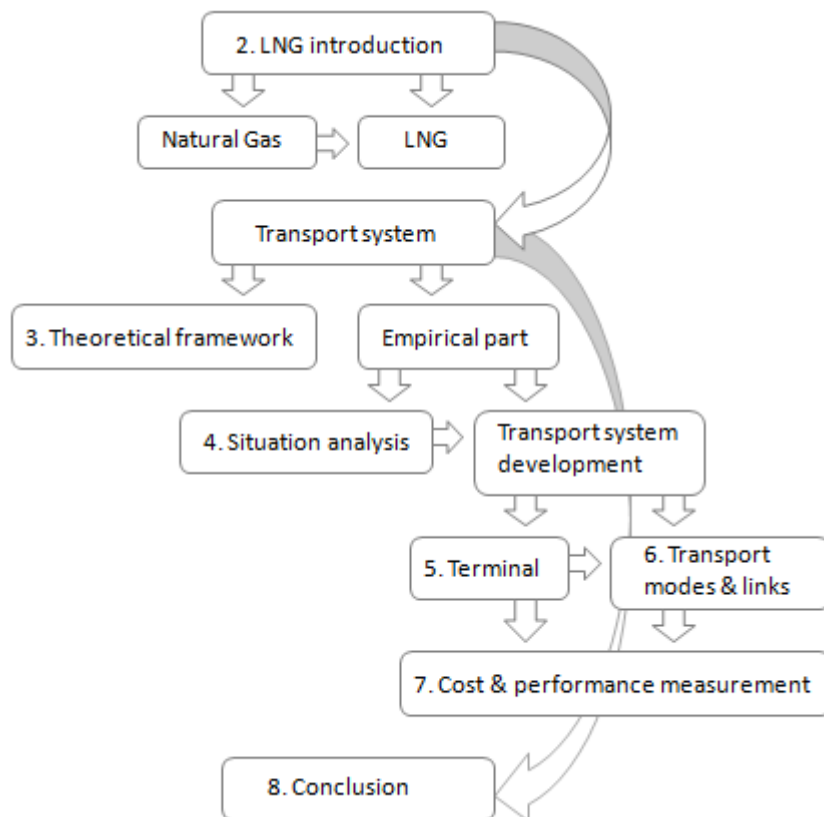


Figure 4 – Thesis structure

2 NATURAL GAS, LIQUEFIED NATURAL GAS (LNG)

With reference to the introduction, LNG is gaining more and more recognition particularly in business and generally in public community. As mentioned in the thesis structure, herein this chapter we have a good look at LNG, the product of emerging attention. A general description of LNG is rendered, subdivided into two parts: the first part about its original form, Natural Gas and the other part about LNG.

2.1 Natural Gas

Natural Gas itself is colourless, shapeless, and odourless in its pure form. Moreover, Natural Gas is combustible, and when burned it gives off a great deal of energy. Unlike other fossil fuels, however, Natural Gas is clean burning and emits lower levels of potentially harmful by-products into the air. (NaturalGas.Org 2004a.)

2.1.1 Composition

Natural Gas is a combustible mixture of hydrocarbon gases. While Natural Gas is formed primarily of methane, it can include ethane, propane, butane and pentane. The composition of Natural Gas can vary widely. (NaturalGas.Org 2004a.) For a better understating, below is a chart outlining the typical makeup of Natural Gas before it is refined.

Table 1 – Typical composition of Natural Gas (NaturalGas.Org 2004a.)

Methane	CH ₄	70-90%
Ethane	C ₂ H ₆	0-20%
Propane	C ₃ H ₈	
Butane	C ₄ H ₁₀	
Carbon Dioxide	CO ₂	0-8%
Oxygen	O ₂	0-0.2%
Nitrogen	N ₂	0-5%
Hydrogen sulphide	H ₂ S	0-5%
Rare gases	A, He, Ne, Xe	trace

2.1.2 Usage

We require energy constantly, to heat our homes, cook our food, and generate our electricity. It is this need for energy that has elevated Natural Gas to such a level of importance in our society, and in our lives. Natural Gas has many applications, commercially, in our homes and in industrial sector. The part gives an introduction of main applications of Natural Gas.

The most common applications of Natural Gas around the home are heating, cooling and cooking. Commercial uses of Natural Gas are very similar to residential uses. The commercial sector includes public and private enterprises, like office buildings, schools, churches, hotels, restaurants, and government buildings. Industrial applications for Natural Gas are many, including the same uses in residential and commercial settings - heating, cooling, and cooking. Natural Gas is also used for waste treatment and incineration, metals preheating (particularly for iron and steel), drying and dehumidification, glass melting, food processing, and fueling industrial boilers. (NaturalGas.Org 2004b.)

After all, accounting for the objective of the thesis topic, Natural Gas is also a valuable source for power generation. Because of the clean burning nature, it has become a very popular fuel for the generation of electricity, while coal is the cheapest fossil fuel for generating electricity but is also the dirtiest, releasing the highest levels of pollutants into the air. Natural Gas has played an increasingly important role in the clean generation of electricity. (NaturalGas.Org 2004b.)

2.2 Liquefied Natural Gas (LNG)

When Natural Gas is cooled to a temperature of about -160°C (-256°F) under the normal atmospheric pressure, it condenses into a liquid and is called Liquefied Natural Gas (LNG). LNG is about 600 times less in volume than the gaseous equivalent. For this reason, LNG can be very useful, particularly for the transportation of Natural Gas. LNG can serve to make economical those stranded Natural Gas deposits for which the construction of pipelines is uneconomical. If Natural Gas has to be transported, it is best done in the liquefied form. (NaturalGas.Org 2004c.)

2.2.1 Properties

Properties of LNG are of great importance to discern as the thesis focuses on logistical operations of importing LNG. Identifying properties of a product assists transporting and cargo handling, preventing and reducing hazards, especially with flammable and explosive cargo like LNG. Table 2 lists LNG properties.

Table 2 – LNG properties (PNG LNG Project, ExxonMobil 2008.)

Toxic	No
Carcinogenic	No
Flammable vapour	Yes
Forms vapour clouds	Yes
Asphyxiant	Yes, but in a vapour cloud
Extreme cold temperature	Yes
Other health hazards	None
Flash point °C (°F)	-188 (-306)
Boiling point °C (°F)	-160 (-256)
Flammability range in air %	5 to 15
Auto-ignition temperature °C (°F)	540 (1,004)
Stored pressure	Atmospheric
Behaviour if spilled	Evaporates as visible clouds, parts of which could be flammable or explosive (if contained) under certain conditions

2.2.2 LNG value chain

Following to the properties, we now go over LNG value chain, which is a four stage process - upstream and gas processing, liquefaction, shipping and re-gas:

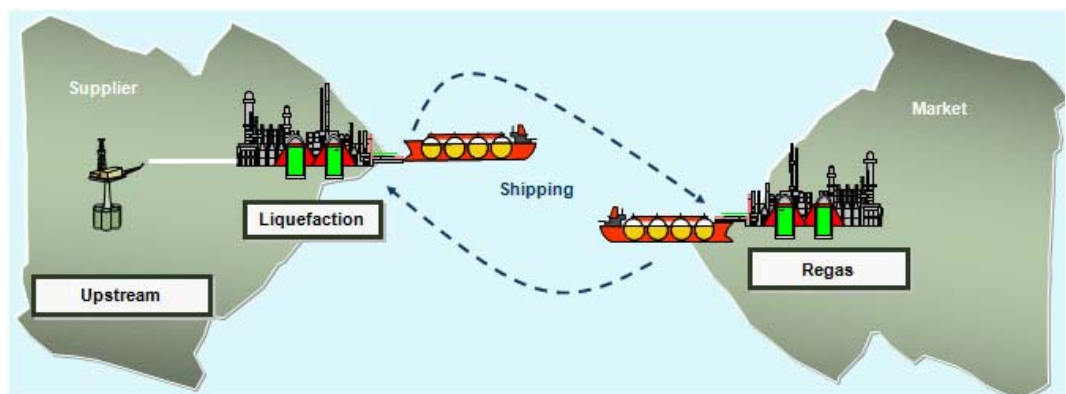


Figure 5 – LNG value chain

Upstream typically represents the process of extracting gas from a subsurface reservoir and transporting it to a liquefaction facility. The upstream activities of exploration and production tend to be characterized by high risk and therefore high returns. Typical upstream project costs can range from US\$ 0.50 to US\$ 4.00 per mmBtu. (Pegaz 2009.)

Subsequent to Upstream, in Liquefaction, some of the non-methane components such as water and carbon dioxide are removed to prevent them from forming solids when the gas is cooled down to about LNG temperature (-160°C). Consequently, LNG is typically composed mostly of methane. The liquefaction process entails using refrigerants to cool the clean feed gas. (Gorgon Project, Chevron 2009.) LNG is then typically stored in above ground or in-ground storage tanks up to 200,000 m³. Liquefaction plants require large capital investment and have a high return (Pegaz 2009.).

Once liquefied, LNG is transported in specialized ships which keep the LNG in a super cold cryogenic state. Nevertheless, a small amount of LNG still vaporizes or "boils off" during transit given that no insulation system is faultless. This boil-off auto-refrigerates the remaining LNG in the compartment, thus keeping it in its liquid state. What is more, boil-off is used to supplement bunker oil as fuel for the tankers. (GIIGNL 2009.) LNG ship sizes have steadily increased, now typically 150,000-155,000 m³. LNG Shipping is a relatively low-risk low-profit activity (Pegaz 2009.).

Finally, upon arrival at the receiving terminal, LNG is transferred into cryogenic storage tanks and stored remained as a liquid at near atmospheric pressure and -160°C temperature. When demanded, LNG is pumped from the tanks for redelivery. At that time, both heat and pressure are adjusted to return it to a gaseous state for transportation by pipeline. (GIIGNL 2009.) Re-gas facilities vary in size typically between 100-1,000 mmcf/d. The re-gasification terminal may include facilities to modify the specification of the gas.

3 TRANSPORT SYSTEM

From chapter 3 onward, the focus of the thesis on transport system is demonstrated. Within the scope of this chapter, the theory of transport systems is revised in order to familiarise the readers with the research question and outline a framework for appliance into the real case. The flow of the transport system theory is presented beginning with the introduction of transport system, which is the threshold of transport system development. Afterwards, some key theories related to transport system are explored. The section offers the idea of what are necessary to be considered for further in-depth study. In this section, transport modes, transport terminal and distribution planning as well as overall costs and performance are taken into account. Last but not least, frameworks are introduced as useful abstractions of transport systems to conduct transport system analyses and designs.

3.1 Introduction to transport systems

Nowadays, international business is becoming a popular activity, which makes a momentous contribution to the development and expansion of transportation on a global scale. Socially, politically and economically, transportation is important throughout the world. Transportation is a critical part of any global logistics effort. Depicted in figure 6 is the function of transportation within the context of the entire logistics system.

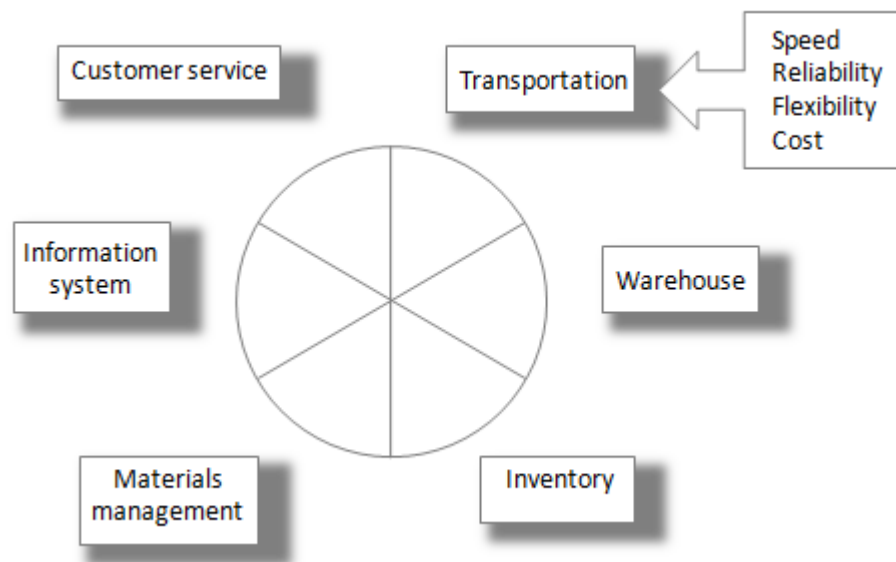


Figure 6 – Transportation in the logistics system (Gourdin 2001, 85.)

The function of transportation is to overcome distance, which is shaped by a variety of human and physical constraints such as distance, time, administrative divisions and topography. It is described as an economic activity different from the others: it trades space with time and thus money. (Comtois, Rodrigue and Slack 2009a, 1.)

Transportation provides two major services: product movement and product storage. Whether the product is materials, components, work-in-process, or finished goods, the basic function of transportation is to move inventory to specified destinations or in other words, is to perform product movement throughout the supply chain. A less visible function of transportation is product storage. While a product is in transportation, it is also being stored. (Bowersox, Closs and Cooper 2010, 193.)

For a broad grasp of a transport system, its components are displayed in the figure below. An overview of components helps understand better what are to be considered in developing and designing a transport system.

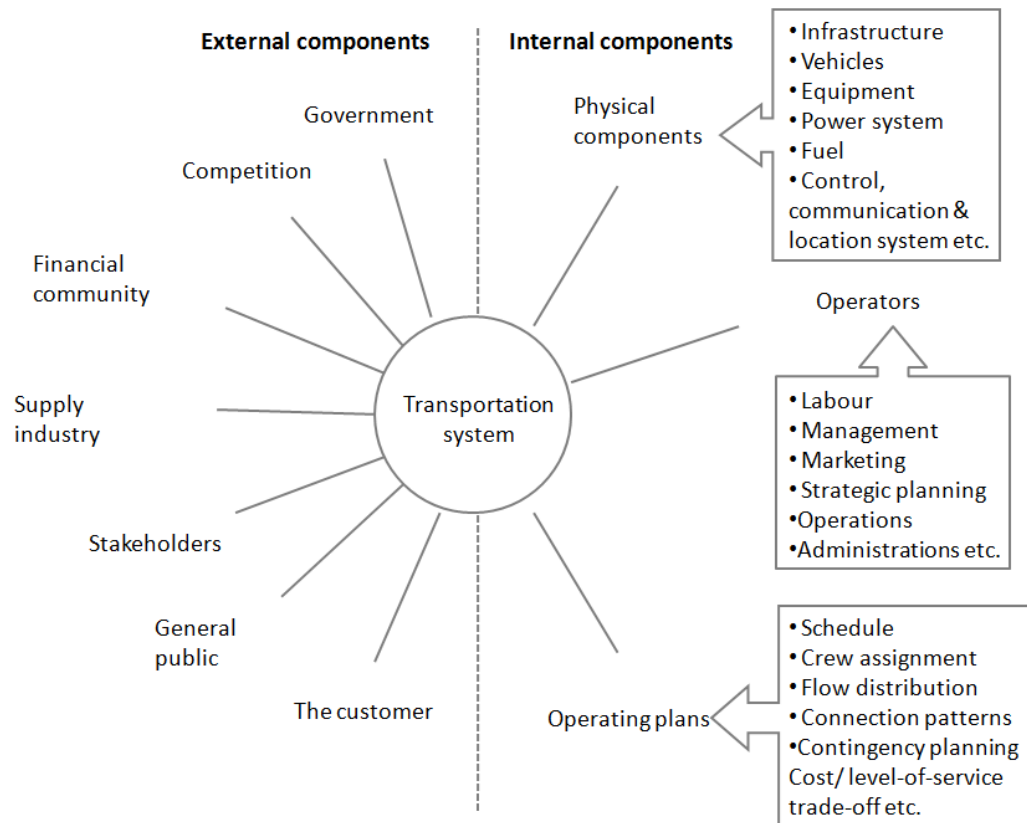


Figure 7 – Transport system components (Sussman 2000, 11-31.)

As can be seen, transport system components are categorized from external and internal perspectives. External components include competition, the supplier, the customer and other entities – government, financial community, general public and all stakeholders. On the other hand, internal components consist of more direct forces such as physical components, operators and operating plans, each of which covers various elements as demonstrated in the figure. We will encounter these components later on in further analysis.

3.2 Transport system and geography

Under this subheading, the writer holds a discourse on transport system and its reciprocity with geography, which have a critical impact on the transport system itself. The subheading content starts with the concept of transportation in geography, then transportation and the spatial structure and finally the geography of transport networks.

3.2.1 Transportation in geography

As stated by Comtois, Rodrigue and Slack (2009a, 1.), there would be no transportation without geography and there would be no geography without transportation; transportation aims to transform and add values to the geographical attributes of freight, people or information, from an origin to a destination. Transportation thus draws intention and interest from geographers, which results in the emergence of transport geography.

Transport geography is defined as a sub-discipline of geography dealing with movements of freight, people and information. It seeks to understand the spatial relations that are produced by transport systems. Transport geography plays an essential role in transportation systems. (Comtois et al 2009a, 7.)

Following discussion identifies three central concepts to transport systems, some of which are at the core of transport geography while others are more peripheral. The transport system can be conceptualized as the set of relationships between the concepts: nodes, networks and demand. We initially get hold of the ideas of these concepts, and subsequently move on to their relationships or in another perspective, their frictions.

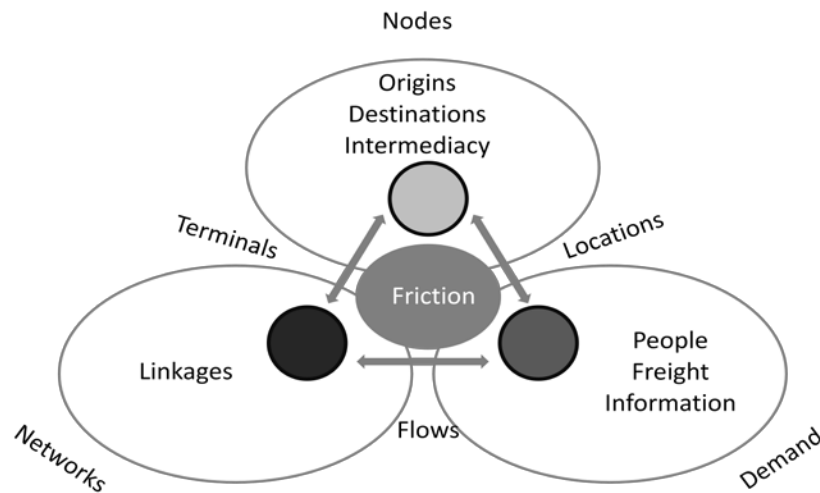


Figure 8 – The transport system (Comtois et al 2009a, 7.)

First among the concepts, transport nodes serve as access points to a distribution system or as transshipment/ intermediary locations within a transport network. This function is mainly serviced by transport terminals where flows originate, end or are being transshipped from one mode to the other. Second, transport networks are a set of linkages derived from transport infrastructures which support and shape movements. Third, transport demand for the movement of people, freight and information specifies demand for the transport services as well as the modes used to support movements. (Comtois et al 2009a, 8.)

The three core concepts above are subject to the three core relationships/frictions: locations, terminals and flows. First, locations are the common factor of nodes and demand. Location decides the accessibility of nodes to the demand they service. Second, terminals facilitate access to the network as terminals are jointly characterized by their centrality and the linkages that radiate from them. Terminal capacity is a potential friction in a transport system. Last, flows, the amount of movement over the network, is a function of the demand and the capacity of the linkages to support them. Flows are mainly subject to the friction of distance. (Comtois et al 2009b.)

3.2.2 Transportation and the spatial structure

As a consequence of the reciprocity of transportation and geography, any movement must consider its geographical setting which in turn is linked to spatial

flows and their patterns. Transportation impacts the spatial structure, as much as space impacts transportation. All the way through history, transportation has structured space at different scales. The mutual link of transportation and spatial structure can be seen at three focal scales: global, regional and local. (Comtois et al 2009a, 54-55.)

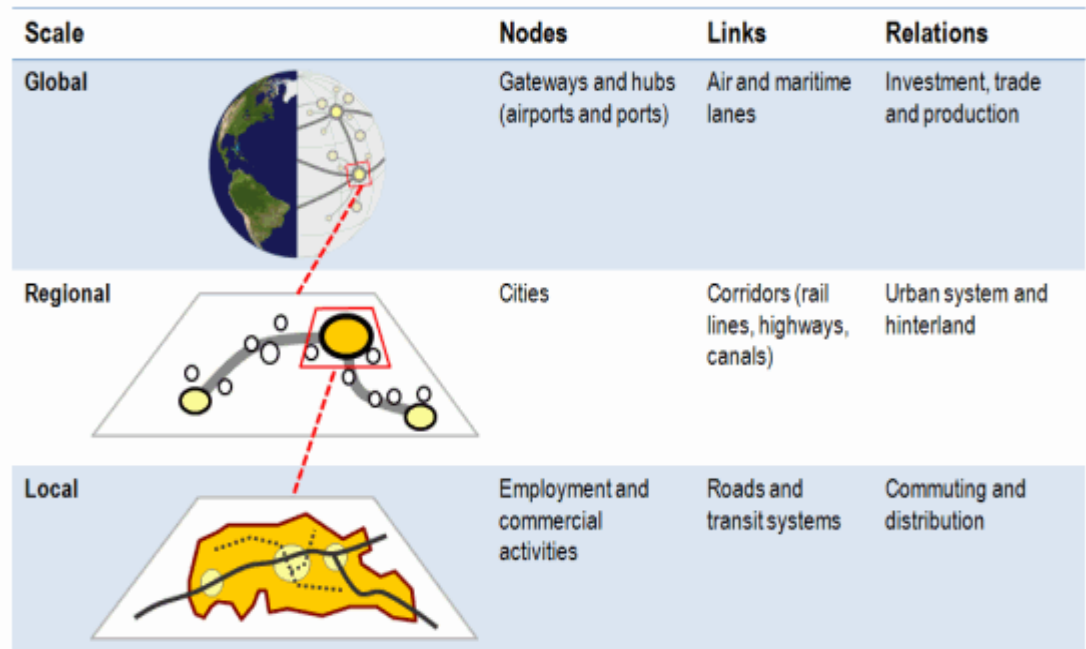


Figure 9 – Scales of spatial organisation for transportation (Comtois et al 2009c.)

The figure provides a perspective of the main elements structuring the organisation of space on the local, regional and global scales. Each of these scales is characterized by specific nodes, links and relations ranging from the local to the global basis.

On the space that transportation covers, major physical constraints can be listed such as topography, hydrology and climate. Physical constraints fundamentally act as absolute and relative barriers to transportation. These constraints hinder transportation with regard to mode choice, level of service, costs and other operational activities. (Comtois et al 2009a, 9.)

First, topography features geographical settings such as mountains and valleys, which exert tremendous influence on the transport system. It can impose a natural convergence of routes, resulting in an extent of centrality where is of the least physical impediments. (Comtois et al 2009a, 9.)

While land transportation is notably influenced by topography, maritime transportation is greatly influenced by hydrology. Hydrology is the properties, distribution and circulation of water, in other words, the availability of navigable channels through rivers, lakes and seas. It is noteworthy that port sites are also vastly influenced by the physical attributes of the site where natural features (bays, sand bars and fjords) protect port installations. (Comtois et al 2009a, 9-10.)

In another manner, climate exerts its influence on transport modes and infrastructure, varying from negligible to severe. Climate primarily composes of temperature, wind and precipitation. Under hazardous circumstances, climate can seriously curtail movements and construction. (Comtois et al 2009a, 10.)

Following the main features of the spatial structure, we move on to factors which are considerable in shaping the spatial structure. In this case, we take into account costs, accessibility and agglomeration. Location decisions ought to be made in a view of minimizing costs. Accessibility of the locations is also a determinant. After all, there is a tendency for activities to agglomerate to take advantage of the value of specific locations. (Comtois et al 2009a, 14.)

All in all, when it comes to transportation, one of the most basic relationships is how much space can be overcome within a given amount of time. When this relationship involves easier, faster and cheaper access between places, this result is defined as a space/time convergence. Several factors involved in space/time convergence include speed, economies of scale, expansion of transport infrastructures and efficiency of transport terminals. (Comtois et al 2009a, 15-17.)

3.2.3 The geography of transport networks

As a matter of fact, transport systems are commonly represented using networks as an analogy for their structure and flows. The term “network” refers to the framework of routes within a system of locations, identified as nodes. There, a route is a single link between two nodes. (Comtois et al 2009a, 17.)

The transport networks set a relationship with space, called spatial continuity. Three conditions to reach such a spatial continuity are ubiquity, fractionalization and instantaneity. Ubiquity is the possibility to reach any location from any other location on the network, thus providing a general access. Fractionalization is the

possibility for a unit of freight to be transported without depending on a group, which is a balance between the advantages of economies of scale and the convenience of dedicated service. At last, instantaneity is the possibility to undertake transportation at the desired or most convenient moment, thus it has a direct relationship with fractionalization. (Comtois et al 2009a, 22.)

As afore mentioned, transport network is considered an analogy, therefore, the writer would clarify the utilised transport network for in-depth study. Corresponding to its complexity, transport networks show variation in categorizing criteria. Among the basic types, the writer puts focus on the network featured with modes and terminals.

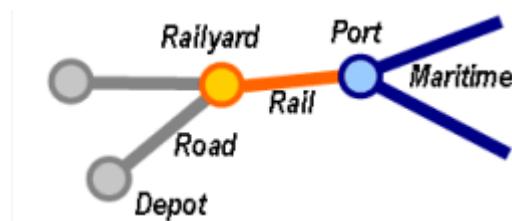


Figure 10 – A transport network featured with modes and terminals (Comtois et al 2009a, 21.)

3.3 Transport modes

Referring to the utilised transport network type, the writer now turns the discussion to one of its features - transport modes. Subsequent to introduction of the function, the subheading reviews the transport modal characteristics and the concept of intermodal transport.

3.3.1 Function of transport modes

Transport modes are a vital component of transport systems for they are the means by which mobility is supported. Each transport mode has its own characteristics and thus criteria, and aims to adapt to serve the specific demands. This adaptation leads to marked differences in the ways the transport modes are made use of and deployed in different locations in the world. Recently, there is a tendency to integrate the modes through intermodality and link the modes more directly and strongly into production and distribution activities. (Comtois et al 2009a, 127.)

There are five basic transport modes including rail, road, water, pipeline and air. A general analysis of transport modes demonstrates that each has key operational and commercial advantage and properties. Modal choice is derived by comparing the available modes and selecting the one that meets the best the requirements. (Comtois et al 2009a, 142.) In the following section, with a view to put forward a proposal of modal choice, transport modal characteristics/criteria would be revealed.

3.3.2 Transport modal characteristics

The description below provides some fundamental characteristics of five listed transport modes: rail, road, water, air and pipeline. Based on the characteristics, modal choice decisions are made.

Table 3 – Transport modal service characteristics (Gourdin 2001, 86.)

	Rail	Road	Water	Air	Pipeline
Speed	Slow	Fast	Very slow	Very fast	Slow
Cost	Low	High	Very slow	Very high	Very slow
Reliability	Medium	Medium	Low	Very high	Very high
Door	Sometimes	Yes	Sometimes	No	Sometimes
Packaging needs	High	Medium	High	Low	Nil
Risk of loss and damage	High	Medium	Medium	Low	Very low
Flexibility	Low	High	Low	Very low	Very low
Environmental impact	Low	High	Low	Medium	Low

Each transport mode more or less exhibits differences compared with the others in terms of speed, cost, reliability, packaging needs, risk of loss and damage, flexibility and environmental impact. In addition to the basic ones, explicitly there are more criteria for modal choice. Further discussion is held on focal transport modes within the scope of the thesis.

Sea transportation, due to its nature, is only economic for long hauls, in most cases country-to-country deliveries. Usually, three legs are necessary: factory to dock, port to port, port to livery location. It is significantly useful for bulk products without size limitations and inexpensive in general, however, only feasible where ports exist. Likewise, inland waterway transportation shares most commons with sea transportation and limited to where there are inland waterway networks. (Waller 2003, 539.)

A pipeline is particularly and only suitable for products in liquid or gaseous form, for example petroleum and chemical products, and coal in the form of slurry. The pipeline itself is infrastructure as well as carrier, thus this mode only works with pipeline infrastructure. On the other hand, a pipeline is advantageous for relatively low cost, continuous flow and ability to cross any terrain. (Waller 2003, 539.)

Road transportation is especially an appropriate mode over short distance with flexibility regarding size and time. It simply involves one leg from supply site to demand location. Nevertheless, its disadvantages are considerable in a way that it can be affected by weather conditions, labour unrest and traffic jams. (Waller 2003, 539.)

3.3.3 Intermodal transportation

In transportation, there are cases when intermodal transport solution is utilised. This utilisation takes advantages of each mode over the segments in a system where it is respectively the most efficient. Available intermodal combinations are rail-road, road-water, road-air and rail-water. Commonly superior to single transport mode, intermodal combinations offer specialized or lower cost services. (Ellram 1998, 219.)

From a functional and operational perspective, two components are involved in intermodalism: transmodal transportation and intermodal transportation.

Transmodal transportation is the movements within the same transport mode. As for transmodal road, it mainly takes place at distribution centres, which have become strategic elements in freight distribution systems. (Comtois et al 2009d) This concept is in-depth revised under the subheading with respect to distribution centres later on.

On the other hand, intermodal transportation is the movements from one transport mode to another, generally occurring at a purposely designed terminal. Intermodal transportation enables cargo to be consolidated into economically large units optimizing the use of specialised handling equipment with a minimum of labour, in order to enhance logistics flexibility, diminish delivery times and minimize operating costs. (Comtois et al 2009a, 332.)

Altogether, four major functions defining an intermodal transport chain are composition, connection, interchange and decomposition (Comtois et al 2009d.):

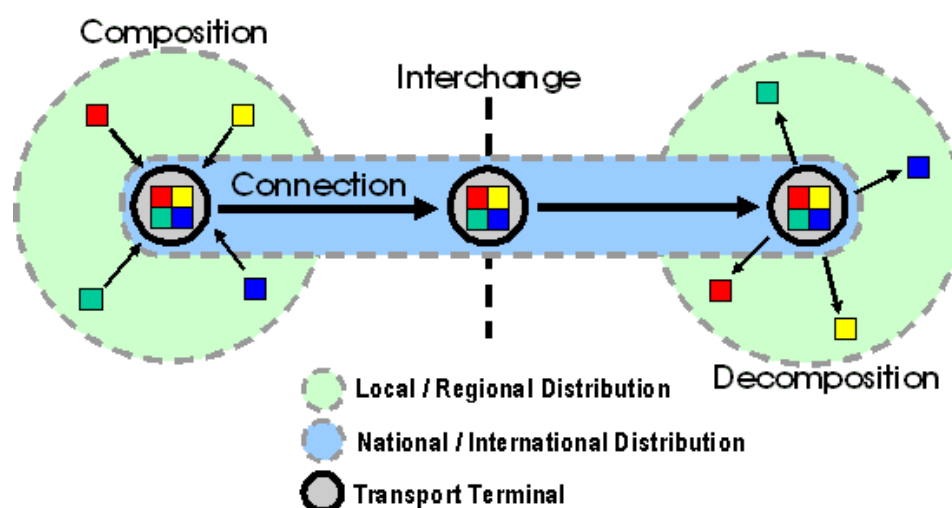


Figure 11 – Intermodal transport chain (Comtois et al 2009d.)

Referred as the first mile, composition is the process of consolidating freight at a terminal that offers an intermodal interface between a local/regional distribution system and a national/international distribution system. (Comtois et al 2009d.)

Second, connection assists a consolidated modal flow between at least two terminals, on the national or international scale. (Comtois et al 2009d.)

Third, interchange, the major intermodal function takes place at terminals which support an efficient continuity within a transport chain. These terminals, likewise to intermodal flow, are dominantly within the realm of national or international freight distribution systems. Among intermodal terminals, ports are more popular. (Comtois et al 2009d.)

Referred as the last mile, decomposition is the process once a consignment has arrived at a receiving terminal. Here, it is consolidated and transferred to the local/regional freight distribution system. (Comtois et al 2009d.)

3.4 Transport terminals

As afore mentioned, transport terminals, together with transport modes, feature transport systems; furthermore, they play a strategic role in the efficient continuity within transport chains. For a better understanding of this critical component, this section in general summarizes issues concerning transport terminals.

3.4.1 Function of transport terminals

In brief, a terminal is a set of infrastructures where freight either originates, terminates, or is interchanged. Terminals are central and intermediate locations in the movements of freight. Specific facilities and equipment are usually required to accommodate the traffic under handle. One of the main functions of transport terminals is convergence. (Comtois et al 2009e.)

Transport terminal infrastructures take advantages of a geographical location, constituting a considerable degree of accessibility to local, regional and global markets. Therefore, three major attributes linked with the importance and the performance of transport terminals are: (Comtois et al 2009e.)

Location is a major factor of a transport terminal with the view of serving a large concentration of population and/or industrial activities, identifying a terminal's market area. Locational constraints of a specific transport terminal vary, including port sites. Taking land costs and congestion fact into account, new transport terminals are likely to situate outside central areas. (Comtois et al 2009e.)

Accessibility to other terminals, on the local, regional and global scale, as well as how well the terminal is connected to the regional transport system is of importance. In an example of a maritime terminal, it is not sufficient if it merely handles maritime traffic but poorly linked to its market areas through an inland transport system. (Comtois et al 2009e.)

Infrastructures are also a key point for supporting a terminal's operations. They are obliged to accommodate traffic in the time being and in the future with new technological and logistical changes. Consequently, nowadays' terminal infrastructures call for substantial investments and structures compared with earlier. (Comtois et al 2009e.)

Terminals fall into two categories: core and ancillary. As illustrated in the table below, core characteristics refer to what a terminal needs to operate, such as infrastructure and equipment while ancillary characteristics tend to be more value added: (Comtois et al 2009e.)

Table 4 – Main characteristics of freight transport terminals (Comtois et al 2009e.)

Core	Infrastructure	Modal access (dock, siding, road), unloading areas
	Equipment	Intermodal lifting equipment, storing equipment
	Storage	Yard for empty and loaded containers
	Management	Administration, maintenance, access (gates), information systems
Ancillary	Trade facilitation	Free trade zone, logistical services
	Distribution centres	Transloading, cross-docking, warehousing, temperature controlled (cold chain)
	Storage depot	Container depot, bulk storage
	Container services	Washing, preparation, repair

3.4.2 Intermodal terminals

Succeeding to the function, we now come to a noteworthy concept: intermodal terminal – a terminal which can accommodate several modes of transportation. There are three major types of intermodal terminals: port terminals, rail terminals and distribution centres. Each one has its own locational and equipment requirements. Herein, the discussion emphasizes only two: (Comtois et al 2009e.)

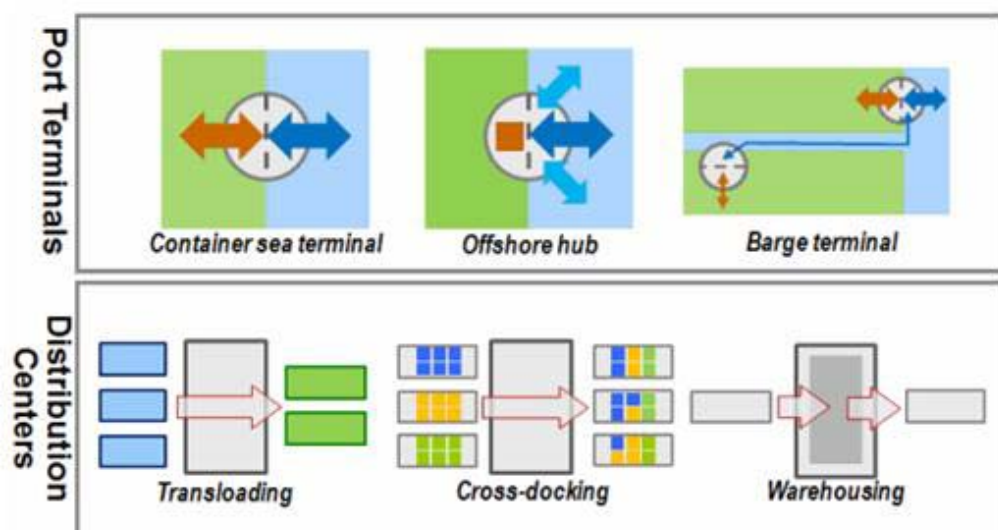


Figure 12 – Two types of intermodal terminals (Comtois et al 2009e.)

Port terminals are the most substantial intermodal terminals as regards traffic, space consumption and capital requirements, falling into three specific terminals as follows. A sea terminal offers an interface between the maritime and inland systems of circulation. In case of little, if any, hinterland connections, offshore hub terminals are the resort. Offshore hub terminals act as buffers for loading between ships. With accessible inland river systems, barge terminals can be developed linked with major deep sea terminals. (Comtois et al 2009e.)

Distribution centres characterize a distinct category of intermodal terminals, covering transmodal operations, conferring an array of value added to the freight. Values are added through three major types of function. A transloading facility principally transfers the consignment from maritime containers into domestic containers or truckloads, or vice-versa. Besides, cross-docking often takes place in the end of the retail supply chain. With limited space, goods are received at one door of the distribution centre and shipped out through the other door on a very short amount of time without putting them in storage. Warehousing is still a standard function in a majority of distribution centres. (Comtois et al 2009e.)

3.4.3 Distribution centre selection

Before getting down to how to select a distribution centre, we foremost get a clearer picture of distribution centres. As described above, distribution centre is an intermodal terminal. In another perspective, it is a facility or a group of facilities with mission of consolidation, warehousing, packaging, decomposition and other functions related to handling freight. For convenience, distributions centres are commonly in proximity to major transport routes or terminals. (Comtois et al 2009a, 326.)

Despite of warehousing facilities in majority of distribution centres, this function has, gradually and significantly, receded. Road-based distribution centres are of increasing momentum toward transmodal operations in lieu of warehousing due to time constraints in freight distribution. The true time-dependent intramodal facility remains the cross-docking distribution centre. (Comtois et al 2009e.)

In planning a transport system, the planner often confronts the questions whether to adopt distribution centres and/or how to establish or select the most favourable.

In his book, Waller (2003, 537-538.) points out some considerations in establishing or selecting a distribution centre:

- First, is the distribution centre really necessary? Is it profitable? Minimizing the number of distribution centres may reduce costs.
- Would it be more cost effective to subcontract (outsource) the distribution centre function rather than the company itself operates the distribution centre?
- How is accessibility and proximity to suppliers and clients?
- What handling equipment will be necessary and should they be leased or purchased? How much does it cost to entirely automate the facility?
- What would be inventory holding costs and overall operating costs including labour, equipment, and capital costs of the facility?
- What is a facility layout for efficient operations? What is the maximum capacity? Is it possible to operate at close to capacity and expand capacity?

3.4.4 Port terminal location

Port terminals handle the greatest amounts of freight, even more than other types of terminals in total. To handle large transshipments of freight, port terminal infrastructures have to facilitate convergence between inland and maritime transportation. In view of the operations of maritime transportation, port locations are restricted to some specific sites. As illustrated below, there is a vast array of port sites, predominantly defined by geography: (Comtois et al 2009f.)

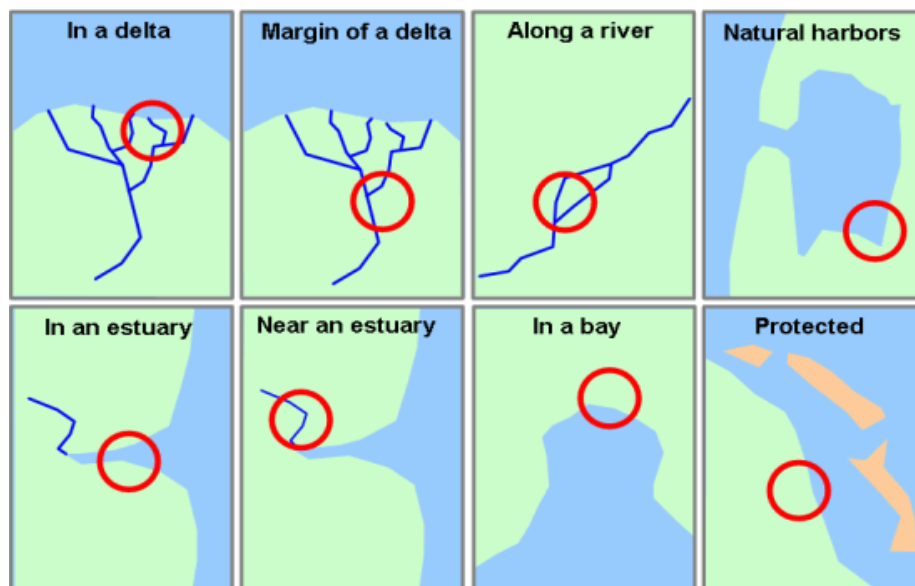


Figure 13 – Port sites (Comtois et al 2009f.)

The figure shows several mainland ports which are linked to a major river. There are ports in a delta, at the margin of a delta, in an estuary, near an estuary or along a river. The rest are seaports which have direct access to the sea. They are in bays, natural harbours, or protected locations.

A port terminal, in some perspective, is considered a warehouse. Therefore, there are many other factors influencing port terminal site selection as in case of a warehouse. As can be seen in the table as follows, there are a variety of factors in site selection which are subsequently used as input for a quantitative approach to site selection.

Table 5 – Factors in site selection (Waller 2003, 50-65.)

Infrastructure	Communication	Cable and satellite connections (telephone, fax, computer etc.)
	Transportation	Facilities and network for raw materials, finished goods and personnel
Staffing	Labour costs	Basic salary/wages, social charges (insurance, pension, education etc.)
	Productivity	Measured by the output divided by the input of resources, or labour cost
	Education level	How much training would be required, what are the training facilities available
	Labour and plant technology	Sophistication of labour to operate according to specification designs
Inherent local conditions	Climate	Warm or cold climate, weather
Construction	Land cost	Cost of land, including taxes
	Land preparation	The work necessary to prepare land for the facility construction
	Construction labour	As opposed to operating labour
	Expansion possibilities	For there may be need for expansion after the facility is built
	Zoning regulation	Laws regarding the construction in a particular place
	Material availability	Such as cement, fibreboard, wood, and construction steel
Proximity to resources	Raw materials	The material used for production
	Process and utility water	For instance, plant using a large quantity of utility water for cooling or processing need to be located near water supply
	Power supplies	Requirement for reliable power supplies or backup power facilities

The applied quantitative approach to site selection is weighting the selection criteria. Herein, the site with the highest overall value would be the preferred location. The procedure of the approach is as follows: (Waller 2003, 66-70.)

- Select the site criteria that are considered the most important for the site.
- Assign a weighting factor, F , to all the site criteria according to their importance to the selection.
- Apply a numerical score, S , for all the site criteria for each possible location being considered.
- Multiply the weighting factor by the numerical score, $F*S$ for each site, and for each criterion.
- Sum the total $F*S$.
- The value $\sum(F*S)$ that is the maximum indicates the preferred site

3.4.5 Transport terminal operational layout

As transport terminals partly perform the function of a warehouse, their layout and design is significant identical to operational layout planning of warehouses. To plan and construct a good warehouse layout is essential, as it can increase output, improve product flow, reduce costs, improve service to customers and provide better employee working conditions (Ellram et al 1998, 294.).

Within a port area, port capacity is an important issue to the terminal. How many ships can be there at any one time? Nowadays, there exists a tendency toward larger ships in view of economies of scale, which stresses more importance on port capacity. All this is a part of an improvement of intermodal capacity. (Sussman 2000, 269-270.)

In addition to port capacity, other factors affecting warehouse size include customer service levels, size of market or markets served, level of pattern of demand, number of products marketed, size of the products or products, materials handling system used, throughput rate, production lead time, stock layout, aisle requirements and office area in warehouse. (Ellram et al 1998, 286.)

Particularly to manufacturing layouts, the following considerations are to be taken. The layout, according to types of material, must insure sufficient structural strength of walls, ceilings and floors for machines and heavy equipment,

insulation from noise and vibration. Environmental and safety regulations are as well considerable for, example acceptable noise levels, adequate lighting, heating, air conditioning, and that flammable or explosive products should be far away from personnel areas. It is advisable to have sufficient working area for control and maintenance procedures. (Waller 2003, 226-227.)

Common manufacturing layouts are functional layout, cellular manufacturing and assembly line. Particularly in the scope of the thesis, a fluid flow layout is in use. Fluid flow layouts apply to continuous manufacturing operations of oil refineries, chemical facilities and other pharmaceutical and food products. The processing involves activities for instance heating, distillation, catalytic transformation, cooling, mixing or fermentation. Fluid layout integrates pipelines, reaction vessels, and heat exchangers. Also due to this, it is often limited to specific products. The layout is rigid, requires a high capital investment, and, once in place, is difficult to adjust. The workforce is limited to a few personnel who manage the facility operations from a control room incorporating a sophisticated network of automatic process control systems. (Waller 2003, 227-232.)

3.5 Transport operations

Strategic plans, referring to the most discussed issues so far, handle the transportation function as a whole from collection point to destination, involving decisions such as selecting transportation modes, determining number and locations of warehouses. On the other hand, an operating plan, in line with the strategic plan, is concerned about how to implement and control each individual activity. There are a variety of operating activities that are made to keep transportation systems operating in an effective and safe way, as afore listed in the internal components of a transport system. (Sussman 2000, 19.)

Moreover, transport operating plans focus on routing and scheduling of transportation equipment to improve vehicle and driver utilization while meeting customer service requirements. An operating plan necessitates data of network, demand and operating characteristics. Routing is characterized by the network, which is the back-bone of the transport routing system. Demand data represents periodic pickup and delivery needs, which affect scheduling. Operating

characteristics represents vehicle numbers, capacity and time constraints, and costs. (Bowersox et al 2010, 353-355.)

Routing is selecting the shortest route from a set of numerous combinations of possible paths. There are two major dimensions defining an optimal routing. First, a good route selection should achieve cost minimization throughout the transport system. The most direct route is not necessarily the least expensive, given that there are more than only cost affecting the decision. Second, a good route selection should achieve efficiency maximization, by offering a level of accessibility, thus satisfying the needs of regional development. A transport system might increase its efficiency at the expense of higher costs on infrastructures and operations. All in all, to select a good route, we must consider the trade-off of cost and efficiency. (Comtois et al 2009g.)

Another significant element of an operating plan is scheduling. A reduction in the frequency of pickup and delivery might accordingly reduce the costs and labour force. Generally speaking, improved schedule results in greater vehicle utilization, higher levels of customer service, lower transport costs and better management. (Ellram et al 1998, 255.)

3.6 Transport costs

Transport costs are a monetary measure of what are paid to produce transport services. They are comprised of fixed (infrastructure) and variable (operating) costs, varying according to different conditions of geography, infrastructure, administrative barriers, energy, and on how passengers and freight are carried. (Comtois et al 2009a, 97.)

There are five categories of transport costs as specified: transport labour costs, transport equipment costs, transport organisation's costs, handling costs and channel costs. All modes of transportation share the common in these cost categories, however, composition of the categories vary depending on the mode of transport in question. To have a clearer picture of these compositions, an example of costs from a road transportation perspective is taken. The five transport cost categories and their components in road transportation are illustrated in the table below. (Oksanen 2004, 60-63.)

Table 6 – Five categories of road transport costs (Oksanen 2004, 60-63.)

1. Transport labour costs	
These costs are accumulated through personnel carrying out the transport services. These consist of salaries and other benefits paid out.	<ul style="list-style-type: none"> • Drivers' salaries • Direct salary expenses • Other fringe benefits (lunch, travelling and accommodation)
2. Transport equipment costs	
<p>Fixed costs</p> <p>These costs are allocated to equipment either directly or indirectly and are not dependant on the short-term activity level of the equipment.</p>	<ul style="list-style-type: none"> • Depreciation and interest of assets • Insurance costs (traffic, vehicle and trailer) • Traffic fees (vehicle taxes, permits and other expenditure paid to official bodies) • Maintenance expenses (storage and washing of vehicles) • Vehicle administration fees
<p>Variable costs</p> <p>These costs accumulate through the usage of the equipment and directly or indirectly relate to the activity level of the equipment.</p>	<ul style="list-style-type: none"> • Fuel expenses • Repair and service of vehicles • Tyre expenses
3. Transport organisation's costs	
These costs are accumulated through the establishment and running of the transport organisation.	<ul style="list-style-type: none"> • Fixed salary expenses (management and operational personnel's salaries) • Office expenses (rents paid, electricity and heating expenses) • Information flow (telephoning and information systems expenses) • Marketing and public relations • Administration costs (bookkeeping, auditing, legal services) • Research, development and training • Membership fees etc.
4. Handling costs	
These costs are accumulated through the handling of the goods that are being transported, sorted and stored.	<ul style="list-style-type: none"> • Insurance for goods in transit • Warehousing and handling costs • Other handling costs (labelling, outsourcing)
5. Channel costs	
These costs accumulate through the usage of transport infrastructure and systems (some only affect road transportation when combined transport systems are used)	<ul style="list-style-type: none"> • Road, toll, customs, tunnel fees • Railway • Port, vessel and channel fees etc.

With the example of costs in road transportation above, we can flexibly relate to the other modes, with the aid of the table as regards cost structure of each mode, detailed with fixed and variable costs.

Table 7 – Cost structure for each transport mode (Bowersox et al 2010, 209.)

Mode	Fixed cost	Variable cost
Rail	High (equipments, terminals, tracks etc.)	Low
Road	Low (highways in place)	Medium (fuel, maintenance, etc.)
Water	Medium (ships, equipment)	Low (capability for large amount)
Pipeline	High (rights-of-way, construction, control stations, pumping capacity)	Low (no labour cost of any significance)
Air	Low (aircraft, handling & cargo systems)	High (fuel, labour, maintenance, etc.)

In addition to a cost structure, it is crucial to get hold of factors which influence the value of transport costs. Factors influencing transport costs can be grouped into two major categories: product-related factors and market-related factors. Product-related factors include density, stowability, ease or difficulty of handling and liability. In addition to product-related factors, market-related factors consist of degree of intramode and intermode competition, location of markets, nature and extent of government regulation of transport carriers, balance or imbalance of freight traffic into and out of market, seasonality of product movements and whether the product is transported domestically and internationally. (Ellram et al 1998, 217-219.)

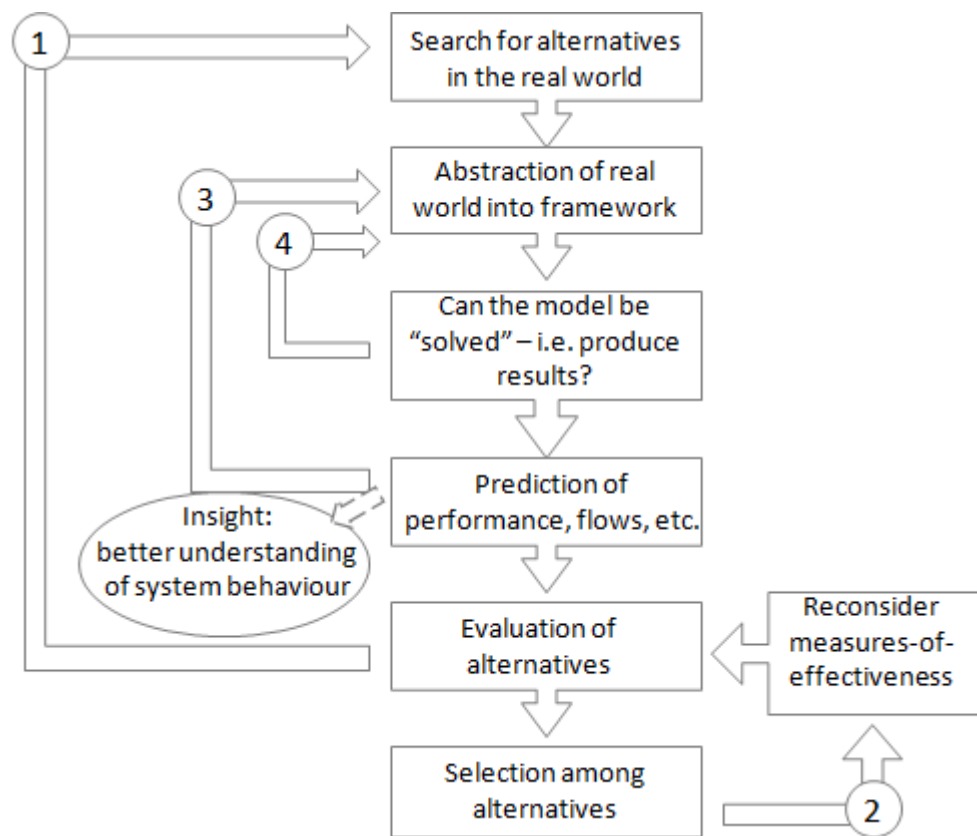
Grasping the categories and affecting factor of costs is the initial step for a cost effective operation improvement, with the view of cost minimization. Areas in which transport operations can be improved are categorized into three groups (Ellram et al 1998, 258.):

- Improvements in the transport system's design and its methods, equipment, and procedures.
- Improvements in the utilization of labour and equipment.
- Improvements in the performance of labour and equipment.

3.7 Framework for transport system analysis

As referred to in the subheading regarding transport networks, the pattern of transport systems, the location of routes, the location of intersections, nodes and terminals can be considered as a network. Therefore, we can conduct an analysis related to a network on behalf of the transport system. Network analyses aim at identifying flows, shortest distances between two given points, or the less expensive route between those points. (Comtois et al 2009a, 337.)

Sussman (2000, 129.) introduces a system analysis framework as follows.



Loop 1: Does the evaluation suggest other alternatives

Loop 2: Are the measures-of-effectiveness appropriate?

Loop 3: Is the abstraction good at predicting?

Loop 4: Development new abstraction

Figure 14 – A system analysis framework: a fourth look (Sussman 2000, 129.)

As can be seen in the figure of the analysis framework, there are four loops which are reverse steps or overviews. The selected solution is further analysed through an activity analysis in the coming discussion.

As transport systems involve various activities, it is necessary to have an overall view of these activities. Through activities individually and altogether, transport systems are operated and thus, costs are accumulated. With an activity analysis, shortage or redundancy of activities can be pointed out for enhance. As demonstrated in the figure below, an activity analysis process is a range of steps.

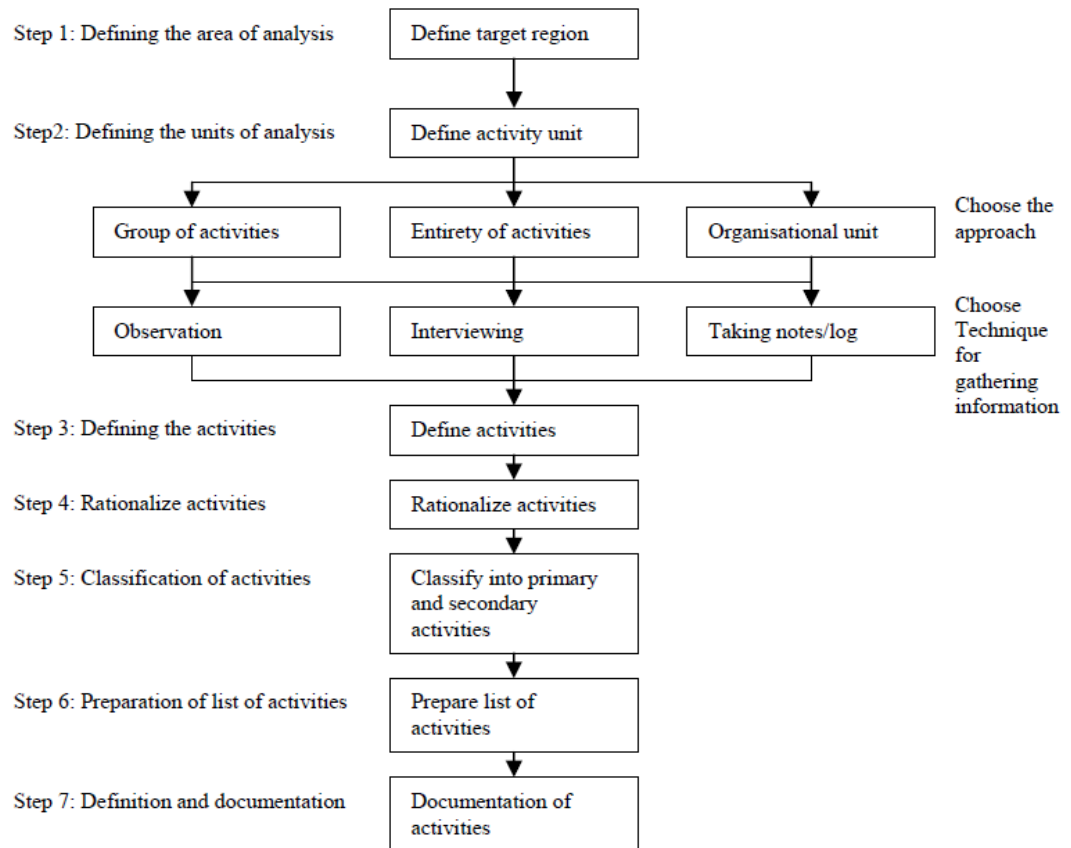


Figure 15 – Process of activity analysis (Oksanen 2003, 104.)

The activity analysis typically is comprised of seven steps as indicated above. The aim of the activity analysis is to identify the transport system related activities. Based on this, cost and performance measurement associated with these activities are documented in order to improve the whole transport system performance.

4 SITUATION ANALYSIS

It must be emphasized that by presenting the current situation analysis, in addition to pinpointing the potential of the LNG import scenario, this chapter also provides readers with external components of the analysed transport system. On one hand, this helps the company investigate and be able to respond to market environmental constraints proactively and reactively. On the other hand, it suggests how external components of the transport system exert an effect on consideration of transport system development. The chapter includes three subparts: micro environment, macro environment and SWOT analysis.

4.1 Micro environment

According to Kotler and Amstrong (2004, 100-101.), success will require working closely with the actors in the company's micro environment. The writer undertakes a study with reference to major actors in the micro environment including customers, competition and suppliers.

4.1.1 Customers

As for customers, it is admitted that the bargaining power of customers to a great extent affects the micro environment of the company. We now identify who are the customers of PV Gas. Foremost, we have a look at the structure of Vietnam's gas sector as follows. The structure identifies players in gas upstream, midstream, retail and end users.

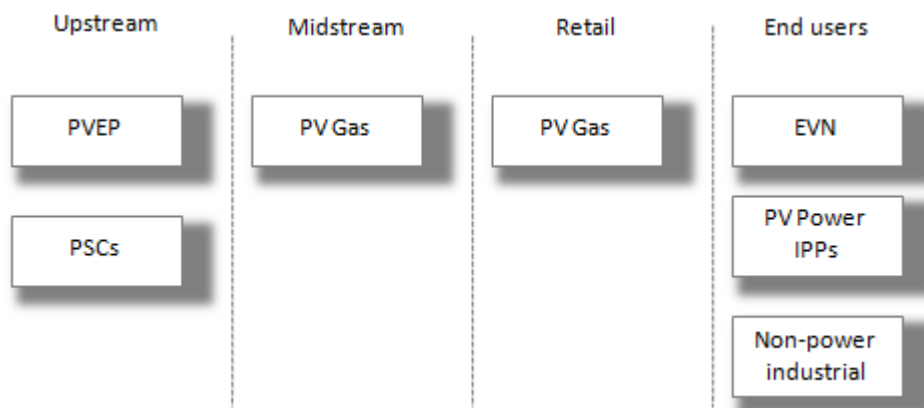


Figure 16 – Structure of Vietnam's gas sector

As can be seen in the figure, the end users of PV Gas are Vietnam Electricity (EVN), PetroVietnam Power (PV Power) – a member company of PVN, independent power plants (IPPs) and non-power industrial sector. In other words, the end users can be grouped into power and non-power industrial sectors. EVN is a key customer, who counts for nearly 80% demand for gas from PV Gas.

The role as an important customer of EVN leads to the company's potentially high customer switching costs. Meanwhile, EVN has several alternative suppliers including own supply sources, among which PV Gas is not the preference, thus would bear a low supplier switching costs relative to PV Gas's customer switching one. Moreover, EVN is a primarily state-owned company in Vietnam. In some sense, governmental support over-empowers EVN in power generation, given that power generation is a strategic unit of the national energy portfolio. Thus, EVN has a significant ability to put its suppliers under pressure. In all, PV Gas is now in an inferior position in a supplier-customer relationship with EVN.

The constrained delivered gas price in the domestic market, which is US\$ 2.2 per mmBtu – 1/4 to 1/3 of the world market price, results in the reluctance of foreign investors in exploitation and development of Natural Gas upstream and transport ashore. Taking this into consideration, PV Gas plans a long term strategy, in which LNG is imported as a leverage to boost Natural Gas domestic price up to the world market price.

Despite a fact that at this moment, EVN has more say in the power generation market, the need for gas supply is in truth likely since Vietnam now lacks electricity in short and medium term. With forecasted GDP growth of about 8.5% per year, the demand for electricity until 2020 is predicted to rise at the pace of around 17% annually. According to the demand in 2007 of about 77 TWh, the demand for electricity would ascend to 125 TWh in 2010 and 600 TWh in 2020. (EVN 2007.)

It is a fact that the key target customer of the LNG import project is EVN.

However, due to the strict control of the government at the moment, the company also considers whether to carry out a 'road map'. In this road map, the non-power industrial sector plays a role as the initial customer, which levers the domestic price of gas in Vietnam up to what is attractive for foreign investment. Foreign

investment will assist PV Gas to reach the target of selling imported LNG to the power sector. Therefore, in the beginning, LNG is imported with a limited quantity for the non-power industrial sector.

Currently there is no demand for gas by the industrial sector in North Vietnam. South Vietnam is the sole non-power industrial customer of gas, especially in Southeast Vietnam. Demand for heating and process has been rising particularly in Binh Duong province, Dong Nai province and Ba Ria-Vung Tau province.

4.1.2 Competition

As stated in the previous subpart, the customers of PV Gas are the power and non-power sectors. Therefore, the company confronts the competition from the other suppliers of its customers. As to the non-power sector, PV Gas currently is the only gas supplier to industrial zones.

As to the power sector, Vietnam has a diverse mix of generation technologies and fuel options. The North is endowed with large hydro power potential and large coal reserves. All existing coal-fired plants are located in the North. This area is regarded as not particularly gas-prone. On the other hand, offshore South Vietnam is gas-prone. As a result, the South is home to all of the country's existing gas-fired plants. Coal-fired plants are expected to build up in the South using imported coal. The following figure shows the structure of Vietnam's power sector involving generation, transmission, retail and end users, and the other figure shows power available capacity by owners, indicating the market share of each.

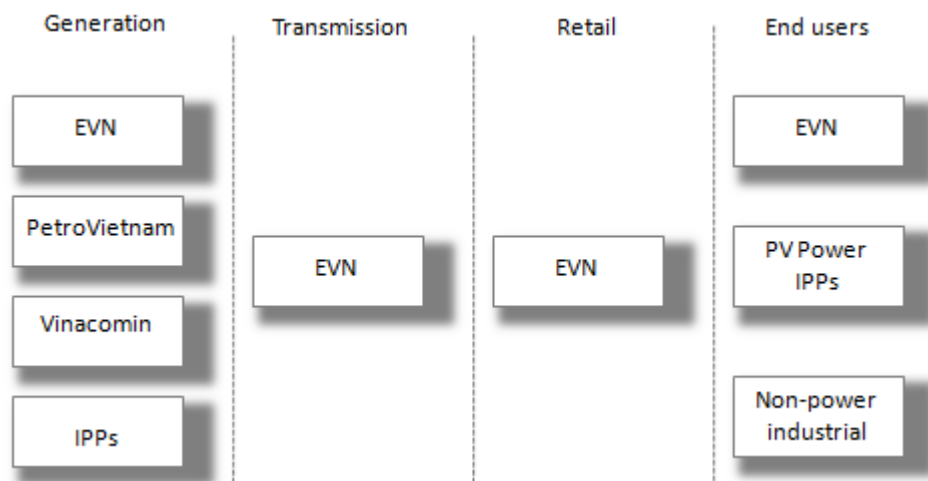


Figure 17– Structure of Vietnam's power sector (PV Gas belongs to PetroVietnam)

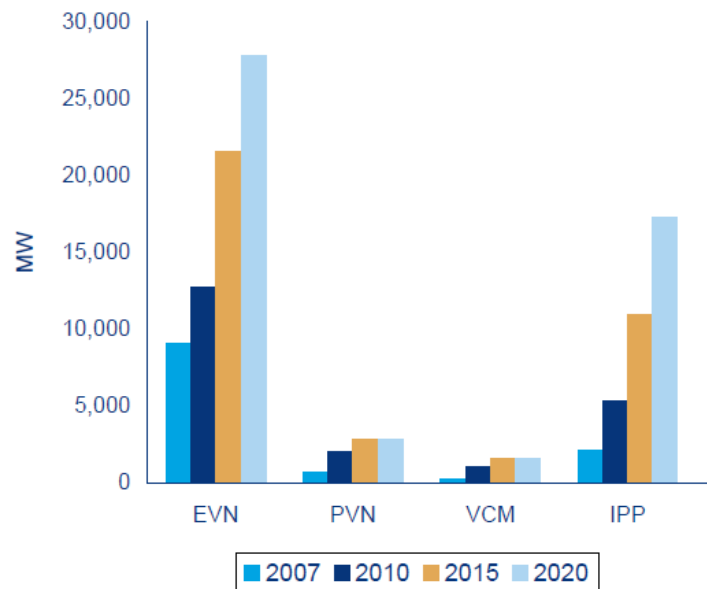


Figure 18– Vietnam power available capacity by owners (PV Gas belongs to PVN)

The superiority of EVN mentioned before, herein, is explained by its widespread operations through a vertical integrate from power generation to end users. EVN is not only the market leader in power generation but also the sole player in transmission and retail. This synergy itself assists significantly each of its individual stages. EVN possesses a variety of hydro plants and is developing more coal-fired plants in the South. As gas production is concentrated in this region, the development of coal-fired plants will exert an influence on the gas market.

Also can be seen in the figures, IPPs take up another considerable segment, using coal and hydro power; Vinacomin uses merely coal; and PV Gas, belonging to PetroVietnam, is the only gas-fired plant owner.

In the current context, PV Gas is a nicher. The gap in EVN's market coverage leaves an opportunity for PV Gas to take advantage of. The company's next mission of the power sector is to import LNG with aim to fulfil demand for power in Vietnam. LNG is expected to become a common source of energy for power generation in the future. As gas is not yet a common source for the power sector, it is necessary for PV Gas to retain the market positioning which differentiates the company's offer. PV Gas differentiated competitive advantages are environment friendliness, and constant and prompt supply. Here, the company has considered the strategy of product development – offering modified product to current power generation market.

4.1.3 Suppliers

First, PV Gas can find supply in uncontracted LNG from existing liquefaction plants (including under construction). However, with excessive demand, the buyer may struggle to get access to the LNG. Examples of uncontracted LNG sources in Asia Pacific/Middle East are North West Shelf, Lumut, Oman, Qatargas, ADGAS. In addition, there is supply from liquefaction plants that could possibly be constructed in the future. For example in Asia Pacific/Middle East, there are Gorgon, Pluto expansion, Browse, Darwin expansion, Gladston, PNG LNG.

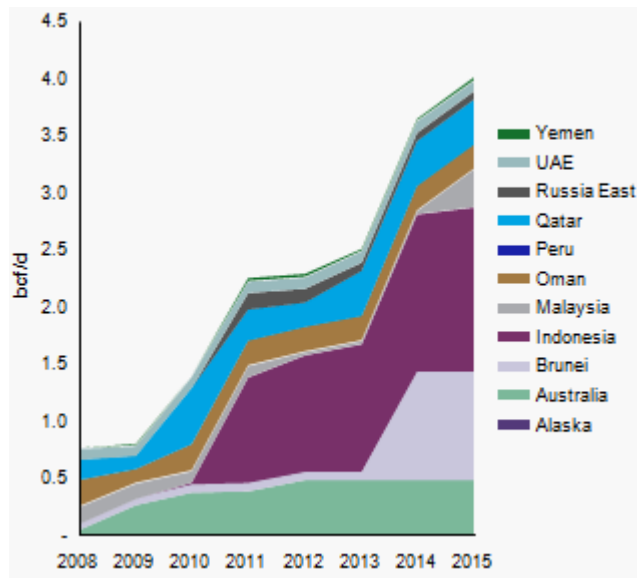


Figure 19a – Uncontracted LNG from existing plants

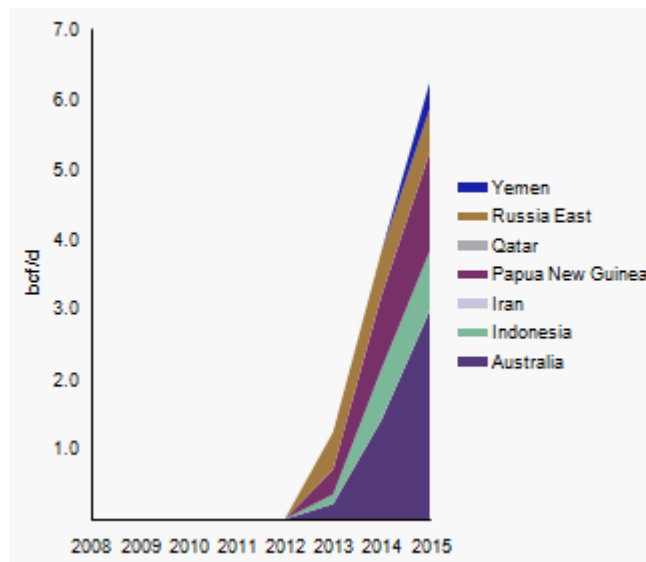


Figure 19b – Uncontracted LNG from possible plants

Second, another supply is LNG diversion. LNG diversion occurs when LNG is contracted but the buyer has the right to divert that LNG to an alternative market. This group is mainly the portfolio players in Asia Pacific/Middle East/North Africa like BG, BP, Total, Shell, Qatar Petroleum.

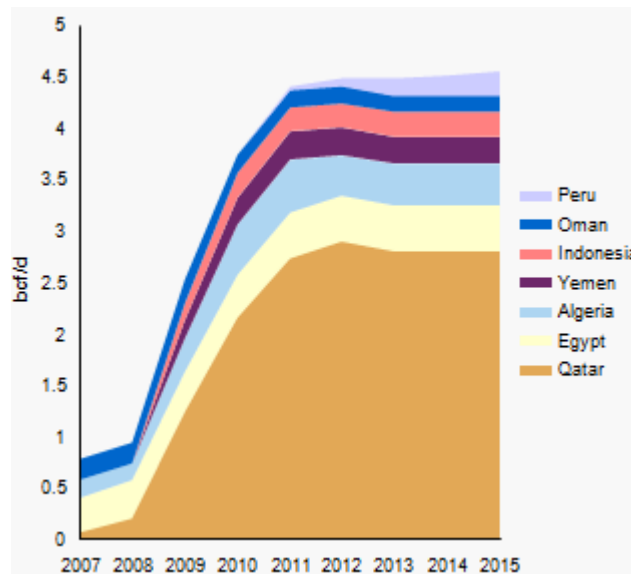


Figure 20 – LNG diversions

4.2 Macro environment

In addition to micro environment, the company and all of the other actors operate in a larger macro environment of forces that shape opportunities and pose threats to the company (Kotler et al 2004, 103.). In this section of the chapter, we examine these macro-environment forces and analyse how they affect the company's operations.

4.2.1 Political factors

As to international activities, political factors are considered crucial. First of all, we have a look at Vietnam's energy policy and regulatory structure involving a range of entities and organisations.

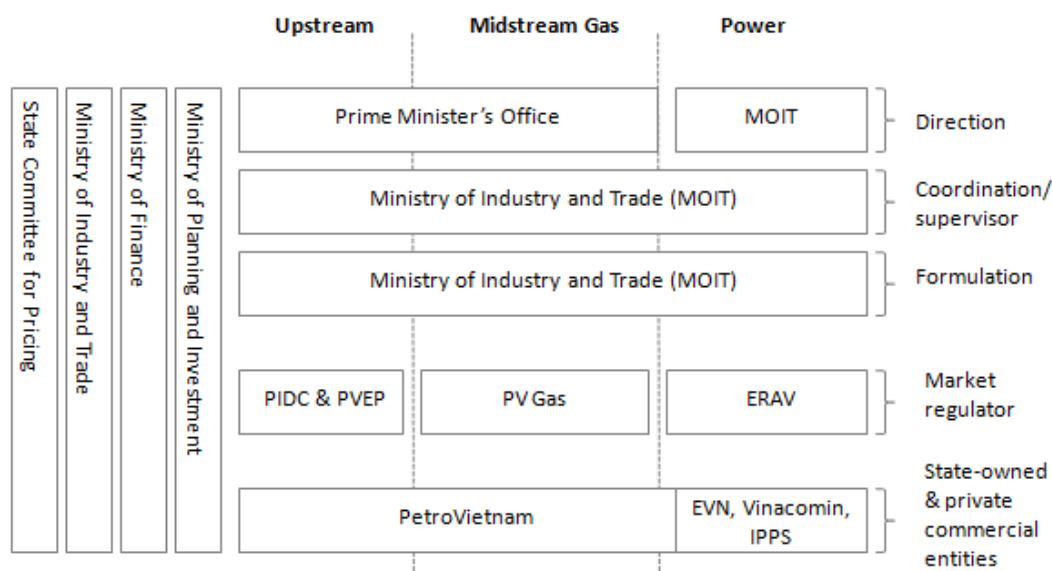


Figure 21 – Vietnam's energy policy and regulatory structure (Vietnam Ministry of Trade 2006a,b,c.)

As we can see in the figure, the Vietnam energy market is lack of a power regulator independent from the supervision of the government. The Electricity Regulatory Authority of Vietnam (ERAV), created in 2005, falls under the authority of the Vietnam Ministry of Trade and Industry (MOIT), indicating that regulatory enforcement will be controlled directly by the government (Vietnam Ministry of Industry 2006d.). Also, it lacks of an independent fuel regulator when all the companies fall under the authority of MOIT.

The Vietnam gas market remains opaque with a lack of clarity on gas pricing policy. The potential for gas price reform is limited by the strict regulation. Nevertheless, the fact that the government recently loosened the control of oil price indicates potential for domestic fuel price to boost up to the world market price.

The Electricity Law, passed in July 2005, calls for the establishment of a transparent, competitive market system to develop the growing Vietnam power industry more efficiently and competitively. The MOIT plans to achieve this by clearer market rules, reduced control of the sector by the government and foreign investor attraction. The law sets a specific time-frame with 3 phases for implementing market reforms: (Viet Law 2005.)

Phase I: Calls for the unbundling of EVN's monopoly in generation. This phase is expected to be completed, with a fully operational and competitive generation market, by 2014. (Viet Law 2005.)

Phase II: Formulates a wholesale market for electricity in Vietnam. This phase moves to an environment where multiple wholesale buyers compete with a number of generating companies and supply options. The current target for MOIT and the regulator to fully implement this is 2022. (Viet Law 2005.)

Phase III: Finalises the introduction of competition into electricity markets in Vietnam by opening power sector to retail players who have the ability to choose various suppliers by 2024. (Viet Law 2005.)

Last but not least, there have been concerns from various stakeholders in the Vietnam energy industry regarding the Vietnam/China maritime dispute. China claims its maritime territory in the South China Sea, which currently overlaps with that of Vietnam.

4.2.2 Economic factors

Vietnam joined the World Trade Organisation (WTO) in January 2007 after a decade long negotiation process. WTO membership has provided Vietnam an offer to the global market and assisted the domestic economic reform process. The workforce in Vietnam is growing every year by more than one-and-a-half million people. In 2008, the labour force was more than 47 million, ranking the 12th in the world. (The World Factbook 2009.)

The world economic turmoil in 2009 has put a great impact on Vietnam economy. Real GDP growth for 2009 could fall between 4% and 5% whereas it was 6.2%, 8.5% and 8.2% in 2008, 2007 and 2006 respectively. Inflation, which reached nearly 25% in 2008, would likely fall to moderate single digits in 2009. In the opposite manner, exchange rate of Vietnam Dong against US Dollar has been increasing, reached 16,548.3 in 2008, suggesting an advantage for import activities. (The World Factbook 2009.)

PV Gas can make use of the low price of gas from Cuu Long and Nam Con Son basins to mix with high price of the imported LNG. By this way, it can retain the

competitive price with other fuels. However, the costs of upstream, in these recent years, have been increasing along with petroleum service market, results in the slow space of gas projects not only in Vietnam but also worldwide.

4.2.3 Societal factors

As for population, it is estimated to reach 86,967,524 in July 2009, with the growth rate of 0.977%. Vietnam's population is young, with nearly 70% between 16-64 years old, meaning a bigger and more willing to work workforce. In this age range, the ratio between 2 sexes is balanced. (The World Factbook 2009.)

As to transportation, Vietnam has 44 airports. There have been constructed pipeline systems with 42 km for condensate and gas, 206 km for refined products. Roadways take up 222,179 km, ranking 24th in the world while waterways take up 17,702 km, ranking 8th in the world with 5,000 km navigable by vessels up to 1.8 m draft. With respect to merchant marine, Vietnam is experienced with 387 vessels carrying various goods. (The World Factbook 2009.)

The concern for environment in Vietnam is increasing. Following the recent fast modernization without a proper environment control, the effect of pollution is obviously spreading and degrading the quality of atmosphere and indirectly the living. Renewable and cleaner fuels are gaining preference to the traditional fuels in the energy policy.

4.2.4 Technological factors

All provinces in Vietnam are digitalized and connected to Hanoi, Da Nang, and Hochiminh City. Main lines have been largely increased, and the number of people using mobile telephones is speedily growing. (The World Factbook 2009.)

In the coming years, an important ongoing issue for power development in Vietnam concerns choices of utilised technology with coal, hydro and gas all realistic options. Access to fuel also plays a considerable role in the technology choice. Currently, there is no geothermal or nuclear capacity in Vietnam and it is not expected to develop in the near term.

4.3 SWOT analysis

To sum up pros and cons of the LNG project, a SWOT analysis is presented.

Table 8 – SWOT analysis of the LNG project

Strengths	Weaknesses
<ul style="list-style-type: none"> • Monopoly of gas trade in Vietnam on a large scope basis • Good reputation and record • LNG import project is approved by PVN and the government • Possible mixture of low domestic price and high LNG price to retain competitive edge • Experience in importing and distributing LPG • Offer of a clean and price-competitive fuel compared with oil products • Increase of state income through VAT from LNG trade 	<ul style="list-style-type: none"> • PV Gas's limited gas market in the South • There are not enough LNG facilities at the moment • The presence of the company in power sector is not significant
Opportunities	Threats
<ul style="list-style-type: none"> • Government's loosened control of domestic oil price suggesting potential for higher gas price • Young population meaning a large pool of workforce • Worldwide preference of cleaner fuels to traditional fuels when looking for a long term supply • Membership in WTO assisting international trade 	<ul style="list-style-type: none"> • Strict regulations and complicated procedures • High costs in petroleum projects • Economic downturn's impact on financing a project • More LNG demand than supply, indicating a contract with good terms is hard to get • Limited potential locations for building up an LNG terminal

5 LNG RECEIVING TERMINAL: THE KEY NODE

As said before, establishment of an LNG receiving terminal is the initial step for developing a complete transport system. In other words, the LNG receiving terminal is the key node within the transport system, through which networks are formulated to meet demands. Under this subheading, an analysis of the LNG receiving terminal is conducted based on afore presented frameworks. Foremost, fundamental design data are reviewed so that a concrete planning is made. Subsequently come subsections with respect to site selection and the terminal's operations.

5.1 Design data

Basically, to construct an LNG terminal, design data are required such as LNG composition and quality, LNG carrier data and LNG tank data.

LNG composition and quality

Referring to the subsection introducing LNG, we have a general view of LNG composition. In establishing an LNG receiving terminal, gas quality specifications in general involve heating value, sulphur compounds, carbon dioxide, water content and hydrocarbon dew-point. (Sangeeta 1999, 43-44.)

LNG carrier data

Besides, in order to identify marine and infrastructure requirements, LNG carrier data must be provided. The detail of an LNG carrier not only has influence on marine considerations and berthing facilities but also on unloading facilities. For safety and commercial criteria, a carrier is advised to be able to be unloaded within 12 hours in order to be turned around within 24 hours. The larger the carrier is, the larger infrastructures are required. (Sangeeta 1999, 43-44.)

The following figure and table illustrate details of LNG carriers which results in different marine and infrastructure requirements.

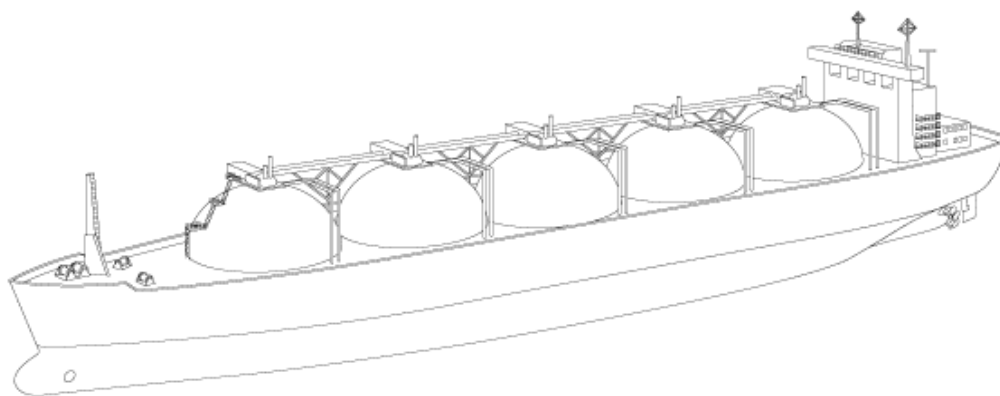


Figure 22 – LNG carrier (World Trade Ref 2009.)

Table 9 – LNG tankers' dimensions (Thoresen 2003, 491.)

Capacity (m ³)	DWT (ton)	Deplace- ment (ton)	Overall length (m)	Length between perps (m)	Beam (m)	Moulded depth (m)	Draft max. (m)
250,000	122,500	177,000	369	354	55.7	31.2	12.8
220,000	108,000	158,000	365	341	53.8	30.5	12.5
200,000	100,000	146,000	340	325	51.3	28.0	12.0
168,000	84,500	125,000	298	285	48.7	28.0	11.9
163,700	84,000	125,000	292	280	45.2	27.5	11.6
145,000	74,400	110,000	288	274	49.0	26.8	12.3
137,000	71,500	100,000	290	275	48.1	28.0	11.3
125,000	66,800	102,000	272	259	47.2	26.5	11.4
87,600	53,600	74,000	250	237	40.0	23.0	10.6
65,000	36,400	52,000	214	204	37.8	21.5	9.8
29,000	22,100	32,600	182	171	29.0	16.5	9.0
1,000		1,600	65		12.0	6.0	3.5

The common size of LNG carrier for long haul now is 145,000 m³. With improvements in design, the new generation of LNG feature improved cargo-carrying capability, improved efficient and lower cost for LNG shipments. The rise of carrier size will result in changes in berth design, shore storage tank capacity, harbour design featuring channel depth and turning basin and harbour

traffic control. (Branch 2007, 65-67.) With respect to economies of scale, the bigger the size of the LNG carrier is, the more beneficial the project is. PV Gas considers utilizing the carrier with capacity of 145,000 m³.

LNG tank data

There are three typical types of tank in the following: (Mustang 2005.)

A single-containment tank consists of a liquid-containing, self-supporting inner wall of 9% nickel steel. An outer carbon-steel wall keeps perlite insulation but does not contain any cryogenic liquid. An earthen dike around each tank contains any LNG spill. (Mustang 2005.)

A double-containment tank is similar to the single-containment tank except for an outer pre-stressed concrete wall. If a tank quality is not ensured, the gas vapours would escape to the atmosphere. (Mustang 2005.)

A full-containment tank provides the inner shell, a concrete outer wall, and generally a concrete roof. The concrete outer wall and roof allow for a higher internal pressure and provide a way to contain LNG and vapours released from the tank. (Mustang 2005.)

5.2 Site selection

Site selection applies generally the framework of system analysis and in combination with the framework of warehouse site selection as demonstrated in the theoretical part.

System analysis

Step 1: Search for alternatives in the real world

During the first step finding locations for the LNG terminal, attention is paid to land availability and expansion potential, topography of the land to guarantee a firm geological base, accessibility to the LNG carrier and the surrounding.

Four locations to build up the LNG terminal have been initially surveyed and preselected including Hai Phong, Thanh Hoa, Khanh Hoa and Ba Ria-Vung Tau.

There are existing ports in these locations as follows (National Geospatial-Intelligence Agency 2009.):

Hai Phong city:	Hai Phong Port 20°55' N- 106°41' E
Thanh Hoa province:	Thanh Hoa Port 10°48' N- 105°46' E
Khanh Hoa province:	Nha Trang Port 12°15' N- 109°14' E
	Cam Ranh Port 11°53' N- 109°10' E
Ba Ria-Vung Tau province:	Phu My Port 10°35' N- 107°02' E
	Saigon New Port 10°46' N- 106°43' E

In accordance with the latitude and longitude of the identified ports, a map of these ports' locations is drawn up below. For detailed maps of the ports, see appendix 2.



Figure 23 – Location of preselected ports (map: The World Factbook 2009.)

Step 2: Abstraction of real world into framework

Select the site criteria that are considered the most important for the site; Assign a weighting factor, F , to all the site criteria according to their importance.

Abstraction of real world into framework is a step where behaviours of the system in the real world are figured out. In the theoretical part, we have identified some criteria in site selection in general. Herein this step, some port selection criteria are added for better evaluation. The criteria taken into consideration in site selection and their weighting factors can be briefly outlined as follows.

Table 10 – Site criteria and weighting factors (F)

Criterion	Note	Weighting factor (F)
Port size	A port with large size assists building up large terminal which can serve large vessels, with a view to economies of scale	2
Shelter afforded	A port with good shelter conditions assists vessels to resist natural restraints (wind, tide, storm etc.)	6
Natural conditions	It is preferable for the site to have sound topography, modest climate and weather	3
Channel access	Conditions of tide, swell, overhead limits etc.	5
Channel depth	The deeper the channel is, the vessel with larger capacity can access to the port	5
Transportation	Infrastructures of roads, railways, waterways and airways	5
Communication	Telephone, telegraph, radio, radio tel., internet	6
Staffing	Labour costs, education level, sophistication of labour in dealing with plant technology	4
Construction	Land cost, land preparation, construction labour, expansion possibilities	4
Resource supplies	Raw materials, power, water, engines	6
Maintenance	Repair and drydock	1

Step 3: Prediction of performance

Apply a numerical score, S , for all the site criteria for each possible location being considered.

Prior to scoring the preselected ports, an overview of these locations is demonstrated in the following paragraphs.

Hai Phong

Hai Phong is a city located in a convenient position for domestic as well as international transportation, with adequate road network, sea routes, inland waterways and airlines. Though the climate is generally moderate, Hai Phong lies within the area affected by monsoon and storms from June to September. The topography has an appearance of low plains typically declining to the sea with some hills in the north. The sound topography is a good base for construction. Hai Phong is endowed with a variety of natural and mineral resources especially limestone which is a valuable material for cement industry. (Hai Phong Official Website 2003a.)

Hai Phong itself is not only a seaport city but a centre of politics, economy, culture, science and technology. The population is estimated to reach 1,100,000 in 2020. In its master plan till 2020, the city sets targets to ensure water, power, environmental and communication services. (Hai Phong Official Website 2003b.) The city government has improved investment incentives with supports of land, labour training and other financial assistances (Hai Phong Official Website 2003c.).

Thanh Hoa

Thanh Hoa is located in the North Middle of the country, though on the roadway across the country, it is still a poorly developed province. Thanh Hoa is often impacted in the stormy season due to its barely sheltered location. Nevertheless, in the coming years, Thanh Hoa is striving to enhance its economic and societal growth. It aims to basically become a industrial province by 2020. Currently, Thanh Hoa is noted for its economic zone Nghi Son in the South of the province. Thanh Hoa port is located within this zone. The infrastructures including transportation, power, water and communication are step by step improved. The

focused industries in the region are oil refinery, steel production, thermal power, fishery, cement production, and ship building and maintenance. (Thanh Hoa Portal 2007.)

Khanh Hoa

The location of Khanh Hoa is convenient for road, rail, sea-born and air transportation. Nha Trang, the main city of Khanh Hoa is a national centre of administration, economy, culture and tourism. The local climate is ideal for various transportations. Nha Trang and Cam Ranh are two well-known ports among a range of seaports in Khanh Hoa. (Khanh Hoa Portal 2003a.)

Khanh Hoa is adequately facilitated and endowed with an ideal location for developing seaports. Khanh Hoa's water has the greatest depth in Vietnam and the closest proximity to the ocean and international maritime waters. Recently, infrastructure in the region has got further investment with respect to power and water supplies, transportation and communication. Furthermore, more incentives in terms of land and finance are introduced to encourage projects in the province. (Khanh Hoa Portal 2003b.) The province has abundant human resources due to great attention from the government. The development orientation stresses the importance of building schools of various types such as general schools, vocational schools, higher education and job training. (Khanh Hoa Portal 2003c.)

Ba Ria-Vung Tau

The location of Ba Ria-Vung Tau plays an important role, a gateway of the Southeast provinces and transit place domestically and internationally. The region has good conditions to develop all types of transportation including road, rail, sea and air. The local climate is moderate with few storms. (Ba Ria-Vung Tau Official Website 2003a.)

One of the significant advantages of Ba Ria-Vung Tau is the great potential of seaports. Thi Vai river crosses the region with 25 km long, 600-800 m wide and 10-20 m deep. With this great potential, here are located Phu My centre, the biggest power centre of the country and a diversification of oil and gas projects. (Ba Ria-Vung Tau Official Website 2003b.) The province is also rich with human resource, given that the education is paid with great attention including general

schools, vocational schools, high education and job training. (Ba Ria-Vung Tau Official Website 2003c.)

Accordingly, in the following table, numerical scores are given to all the site criteria for each preselected port. For the detailed ground of scoring, see port indexes in appendix 3.

Table 11 – Ports’ predicted performance (S)

Port	Hai Phong	Thanh Hoa	Nha Trang	Cam Ranh	Phu My	Saigon New
Port size	3	1	2	2	1	3
Shelter afforded	5	4	4	3	4	5
Natural conditions	2	1	4	4	3	3
Channel access	1	3	2	4	1	3
Channel depth	4	3	6	4	7	5
Transportation	6	3	5	4	5	6
Communication	5	3	4	4	4	5
Staffing	3	3	3	3	4	4
Construction	4	2	2	3	2	2
Resource supplies	6	5	4	4	6	6
Maintenance	2	3	3	2	1	3

Note: the highest score is the optimal

Step 4: Evaluation of alternatives

*Multiply the weighting factor by the numerical score, $F*S$ for each site, and for each criterion; Sum the total $F*S$; The value $\sum(F*S)$ that is the maximum indicates the preferred site*

Details of calculating component scores and accordingly total scores of each preselected ports are given in appendix 4. In the table below, total scores of the ports are provided for evaluation.

Table 12 – Evaluation of ports

Port	Hai Phong	Thanh Hoa	Nha Trang	Cam Ranh	Phu My	Saigon New
Total score - $\sum(F*S)$	193	144	168	172	188	208
Rank	2	6	5	4	3	1

As we can see from the scores in the table, the top three ports are Saigon New Port, Hai Phong Port and Phu My Port respectively. According to the framework, Saigon New Port is the preferred site for building up the LNG receiving terminal. On the other hand, to verify and double-check this step's result, the next steps will qualify whether Saigon New Port is the optimal choice. As far as we know, Phu My Port and Saigon New Port is of close proximity, as featured in the port map. The further validation would not significantly change the rankings of these two. Therefore, Phu My Port is left out given that it is the port of the least high score among the three. As a consequence, in step 5 and step 6, two outstanding sites to be reconsidered for selection are Saigon New Port and Hai Phong Port.

Step 5: Can the framework be solved

Step 6: Selection among alternatives

Through the previous steps, we have selected locations in view of direct forces of an LNG terminal. Instead, in these steps, through economical validation, indirect forces are taken into consideration. It is advisable to consider political issues as due to political orientation, the more economic solution is sometimes not selected by the government. However, political regulations in Vietnam are quite complex, thus hard to be predicted. As a result, only economical validation is mentioned herein the framework.

Location close to an industrial zone might be convenient and economic, for instance, the possibility of using in-place facilities. From an environmental perspective, an LNG terminal is considered a clean facility with limited emissions. The main environmental impact may arise due to terminal construction itself and dredging the port and access channel for LNG carrier approach. With seawater vaporization technology, a concern is cold water discharged from LNG vaporisers into the marine ecosystem. In this case, location close to industrial zones does

solve the problem. Sometimes, the discharged cold water can be used to reduce the impact of temperature rise originated from the warm water discharged from other industrial facilities. Then, it does not put a negative, but instead, a positive influence on environment. (Sangeeta 1999, 46-47.)

Besides, there may be substantial demand from nearby industrial zones. As revealed in the section regarding customers, besides main customer EVN, PV Gas considers a plan in which LNG is, at start, sold to non-power industrial sector, to signal LNG market to other stakeholders. Consequently, we now get down to analysing existing industrial zones near Saigon New Port and Hai Phong Port.

Industrial zones (IZs) close to Saigon New Port that can be listed are Phu My IZ with 1500 ha, My Xuan IZ with 800 ha, Cai Mep IZ with 670 ha, Dong Xuyen IZ with 161 ha (Ba Ria-Vung Tau Official Website 2003d.). There is existing demand as well as potential demand for gas from these industrial zones. The demand in the province is forecasted to reach 50 bBtud in 2013 and 70 bBtud in 2020, which is converted to be 0.35 million tons LNG and 0.49 million tons LNG respectively (see appendix 5).

With regard to Hai Phong Port, it is surrounded by three main industrial zones, including Dinh Vu IZ with 1,152 ha, Nomura-Hai Phong IZ with 153 ha and Do Son IZ with 150 ha (Hai Phong Official Website 2003d.). At the time being, there is no gas market in Hai Phong, which is the result of no significant gas mines in close proximity. However, a reason of selecting Hai Phong as a potential site for LNG terminal is the potential demand from South China. In such a case that the demand for LNG of the region surrounding Hai Phong is not substantial or stable enough, a part of LNG is transmitted to South China.

As we can see, the scope of industrial zones surrounding Saigon New Port is greater than those near Hai Phong Port. Furthermore, there is secured demand for LNG in industrial zones in the area of Saigon New Port whereas demand in Hai Phong area is yet-to-find. The situation of Hai Phong area indicates a longer and somewhat unknown time to implement the project, which means more risks. At this moment, there are gas infrastructures in the area of Saigon New Port while there are none in Hai Phong Port. Unsecured local demand and infrastructures hinder building up a terminal in Hai Phong Port. Last but not least, in accordance

with the framework's result, Hai Phong Port ranks after Saigon New Port. Altogether, Saigon New Port is the preferred site for an LNG receiving terminal, unless governmental bodies decide otherwise.

5.3 Operational layout

In the previous section, we have concluded Saigon New Port is where to build up the terminal. Following that, under this section, the discussion is held on the topic of operational layout of the terminal. In general, fluid flow layouts are applied.

According to Vietnam Seaports Association (2009.), Saigon New Port has the depth of 11 m and port capacity of about 40,000 ton. On the other hand, with a utilised 145,000 m³ carrier, the maximum draft is 12.3 m and the dead weight ton (DWT) is 74,400. Hence, there must be activities of dredging and upgrading port facilities. The requirement for upgrading facilities to build an onshore terminal would take time, thus to begin with, it is a convenient solution to use the technology of floating LNG terminals.

5.3.1 Floating LNG terminals

Floating LNG terminals is a category among offshore LNG terminals, to be distinguished from fixed offshore LNG terminals. Floating LNG terminals include Floating Storage and Regasification Unit (FSRU) and Floating Regasification Unit (FRU) if storage is not incorporated into the floating facility. FSRU is the preferred choice in this case as currently there is no LNG storage available. If the FSRU has sufficient storage capacity, Natural Gas can be supplied to consumers for base load operations (on a daily basis) in a continuous and constant manner. (CEE 2006, 21-22.)

A FSRU is comprised of a ship with normal shipbuilding blueprints and standards, attached with a regasification/ vaporization facilities on the main deck of the ship. Since a FSRU is part ship and part terminal, it can either store LNG or receive LNG from other tankers. A FSRU is sited near the port and accommodated with flexible pipeline connection to transfer LNG onshore as demonstrated in the figure below. (CEE 2006, 36-38.)



Figure 24 – Underwater connections for FSRU (CEE 2006, 37.)

LNG tankers of 145,000 m³ with maximum draft of 12.3 m typically need at least an additional about 1.5 m of depth to ensure safe manoeuvrings. This means that the minimum water depth for sitting a FSRU is approximately 14 m. In the same manner with onshore facilities, operations at FSRU involve docking, offloading, storage and regasification. These operations at FSRU share a lot similarity with those onshore, thus, studied in depth later on under the section of onshore terminals. (CEE 2006, 37-38.)

5.3.2 Onshore LNG terminals

When facilities at the port are adequately upgraded, operations can switch from using a FSRU to using an onshore LNG terminal. As explained before, the two qualities, heating value and LNG composition, are of great importance since they affect design of the regasification terminal's equipment. A general layout of an onshore receiving/ regasification LNG terminal is outlined as follows.

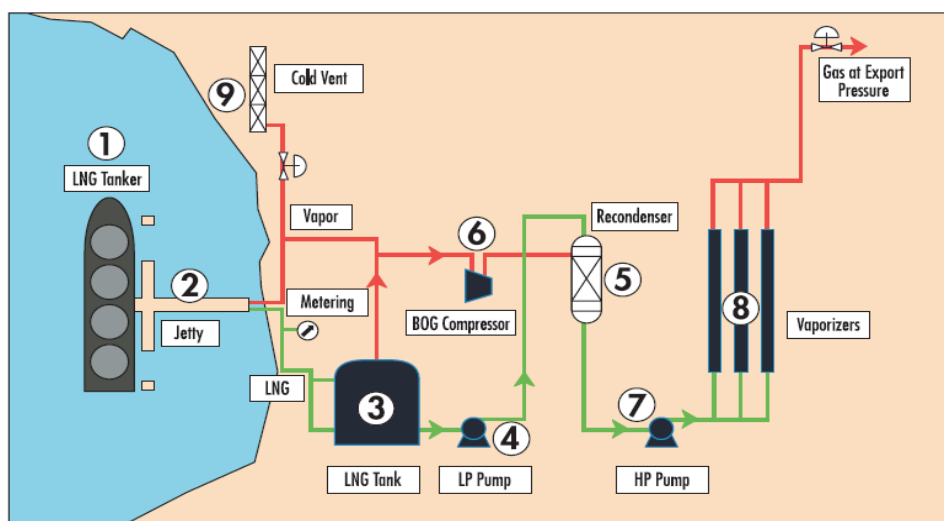


Figure 25 – Layout of an onshore LNG terminal (Canaport LNG 2009.)

Once the LNG tanker (1) is docked and safely moored, LNG is gradually chilled to -160°C . Then, the LNG is transferred onshore with the aid of the pumps inside the ship's tanks and the multi-purpose jetty (2). This jetty is comprised of liquid loading arms and one vapour return loading arm. An insulated pipeline is used to transfer the LNG from the carrier to the terminal's LNG tanks (3) with an unloading rate of approximately $10,000 \text{ m}^3/\text{h}$. The capacity of the tank is $160,000 \text{ m}^3$ and the standard requires at least two storage tanks. Vapours generated in unloading are returned to the carrier via an insulated vapour-return pipeline, in order to keep positive pressure in the ships' tanks, thus a constant flow of pumped LNG. Besides, losses of electrical power, vapour are safely vented through the cold vent (9). When there is demand for Natural Gas, low pump pressures (4) keeps the LNG move from the tanks to the recondenser (5). It is the fact that stored in the storage tank, some LNG is heated to become vapour. This vapour or boil-off gas (BOG) is removed and processed by the BOG compressor (6) before going to the recondenser (5). In the recondenser (5), BOG is recondensed and mixed with the LNG from the low pressure pumps (4). After that, through high pressure pumps (7), the LNG is moved to the vaporizers (8). Here the LNG is turned to Natural Gas and then transported to users with pipeline pressure. (Canaport LNG 2009 and Mustang 2005.)

Several vaporizer technologies in LNG regasification have been developed. Vaporizers can utilise air, seawater or gas itself as the primary heat source. The factors to be considered in choosing a vaporizer technology are initial investment, operational costs, maintenance, reliability, availability, air emissions, water emissions, and environmental footprint and impact. The widely used technologies in use nowadays are seawater-based and gas-based. The operations and costs associated with gas-based vaporizers differ significantly from those of seawater vaporizers: the gas-based requires more space and operating costs compared with the seawater-based. Especially, gas-based technology is not preferable in view of its greenhouse gas emissions. (CEE 2006, 44-54.)

In case that there is sufficient seawater, seawater-based vaporizers are of great economic sense and environmental friendliness. PV Gas sees seawater-based technology a wise solution given that the endowed resource of seawater in Vietnam ports can help efficiently make use of the technology's advantages. There are two main designs using seawater heat including open rack vaporizers

(ORVs) and shell and tube vaporizers (STV). Above all vaporizer technologies, the most commonly used in the world is ORV vaporizer. (CEE 2006, 44-45.)

In addition to fixed facilities, utilities for terminal operations are in a utilities building, with the exception of electricity. Electricity is commonly supplied from a local electricity grid. Offices and control room at the receiving LNG terminal are required to be located away from the process area for safety reasons in case of flames or explosions. (Mustang 2005.) For a detailed illustration, see appendix 6.

5.4 Operations

Likewise to a layout, operations are also of great importance. A critical rule underlying all aspects of handling LNG is safety. Besides safe handling, the main operational issues involve supply and shipping contract, capacity and scheduling.

Supply and shipping contract

In all, operations at the receiving terminal are to a great extent affected by the employed contract. In LNG trade, contracts are on Free on Board (FOB) or Delivered Ex Ship (DES) basis. There are a variety of factors influencing employment of FOB or DES contract. (EIA 2003a.)

The following table summarises pros and cons of FOB or DES in LNG trade, based on which the company considers to make the decision.

Table 13 – Pros and cons of FOB and DES in LNG trade

	Free on Board (FOB) (named port of shipment)	Delivered Ex Ship (DES) (named port of destination)
Pros	<ul style="list-style-type: none"> • Purchaser can use own ships to take cargoes from various suppliers • Control of quantities, routes and schedules • Shipping control authorises advantage over suppliers 	<ul style="list-style-type: none"> • Simpler administration as majority of the responsibility is on suppliers • Lower risk • Potentially lower cost
Cons	<ul style="list-style-type: none"> • Unsecured investment • Potentially higher cost in case of under-utilisation of ship's capacity 	<ul style="list-style-type: none"> • Potentially more expensive due to lower pricing power • Limited flexibility

With a view of good inventory management, it is advisable to arrange an LNG supply and shipping contract about one year in advance. Inventory management may become complicated when some erratic schedules are carried out at the terminal. A good scheduling is crucial especially in case of more than one supplier or shipper. It is possible that two or more ships arrive at the terminal at the same time, which leads to overload for the terminal's infrastructures and operations.

Capacity

For a continuous gas delivery to the market, the capacity should be sufficient to meet the demand in the time between tanker deliveries, demonstrated with the formula: capacity of typical tanker / sendout capacity of terminal = average time between tanker deliveries for continuous Natural Gas output. Therefore, the minimum amount of terminal storage capacity is equal to that of an LNG tanker delivery. Nevertheless, it is common practice to have additional storage volume due to unexpected delays, erratic arrivals and sendout schedules. Ship storage costs 5 to 6 times the equivalent onshore storage. Thus, economic sense can be achieved with buffer storage. (CEE 2006, 21-22.)

Besides storage capacity, capacity of vaporizers and sendout pipelines are also considerable. The sendout pumps and vaporizers should reach the maximum sendout rate. Additional vaporizers can be added with environmental assessments. Together, the sendout pipelines are required to be capable of transporting maximum sendout rate. (EIA 2001.)

Scheduling

A typical LNG ship discharge takes about a 24-hour turnaround time, broken down as follows: 4 hours for customs, immigration, custody transfer measurements, connecting the unloading arms, and cooldown; 12 to 14 hours unloading; 6 to 8 hours for final custody transfer measurements and calculations, disconnecting unloading arms, provisioning, and deberting. An advisable scheduling for one berth at the terminal is one tanker arrival every 3 days. (EIA 2001.) As a result, the annual maximum number of scheduling times is 121 (365 divided by 3 equals 121.67). On the other hand, to meet efficiently the demand, the annual minimum number of scheduling times equals to the annual target demand divided by the terminal's storage capacity.

6 ONSHORE TRANSPORT MODES AND LINKS

The established LNG receiving terminal is the key node in the transport system, based on which links and accordingly modes of the onshore transport are designed. In this heading, onshore transport modes and links of the LNG transport system in Vietnam are focused on. As concluded, the terminal is built up at Saigon New Port where there are substantial demands for gas from both industrial zones and power plants. Consequently, transportations of LNG to industrial zones and power plants are respectively analysed, with respect to transport modes and operational plans.

6.1 Transportation to industrial zones

With confirmed demand from industrial zones nearby Saigon New Port, in the beginning, LNG is not sold to power plants yet. This is due to the unadjusted low gas price paid by EVN. Hence, in this stage, LNG is transported solely to industrial zones. The above description of industry in Ba Ria-Vung Tau shows four key industrial zones in the province. Furthermore, the potential demand from industrial zones is not limited to these. A wide range of industrial zones in Ba Ria-Vung Tau's neighbouring regions including Hochiminh city, Binh Duong province and Dong Nai province (see appendix 7) is currently without the connection of gas pipeline and principally consuming LPG, diesel and fuel oil for heating and processing, which indicates a large pool of demand for LNG.

6.1.1 Transport mode

Though substantial, the demand for LNG from industrial zones is still on a small scale. With small volume, it is common practice to transport LNG by road tankers, rail and even barges. Above all available modes, road tankers show superior performance compared with the others in this case. Since most industrial zones in focus are not located near river ports and railway stations, only road transportation can meet the door-to-door requirement. Transportation by rail and barges calls for construction of new ports and railway stations whereas highways are in place. Low fixed costs and short distance make road tankers more preferable. Moreover, road tankers are of high speed and flexibility.

With road tanker deliveries, LNG is not regasified at the terminal but at the end user locations. A road tanker is comprised of a prime mover and a cryogenic vessel. The transportation of LNG by road tankers from the terminal to end users can be broken down as follows.

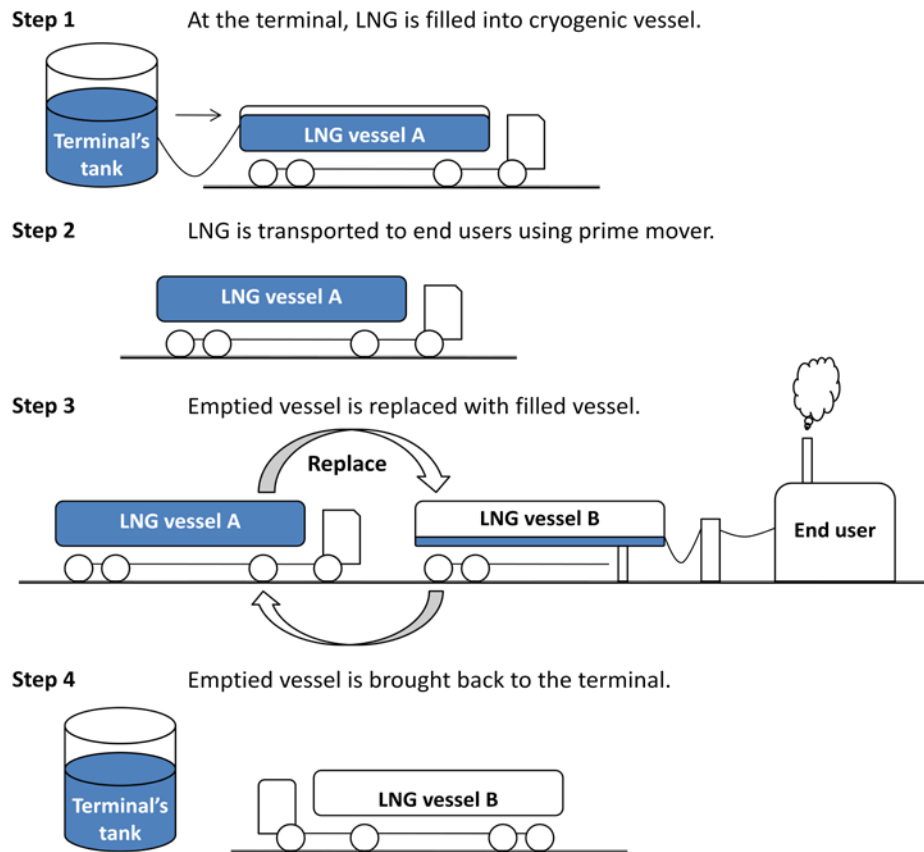


Figure 26 – Transportation of LNG by road tankers from the receiving terminal to end users

The LNG is first filled into an LNG cryogenic vessel at the receiving terminal. This vessel is loaded on a prime mover, which is together called a road tanker. The road tanker transports LNG via roadways and eventually arrives at end user locations. At end user locations, there are small-volume storage tanks which are attached with the regasification unit. In case that there are no storage tanks, it is possible that the arriving vessel is attached with the regasification unit and stays at the end user locations until it is emptied. Then, the arriving filled vessel replaces the emptied vessel. Finally, the replaced emptied vessel is loaded on the prime mover and brought back to the terminal for refill. This transportation helps the operations as flexible as possible. To a specific end user, the transportation can be either on a daily basis or erratic.

6.1.2 Operations

An operational plan for transportation of LNG to the industrial zones is studied in this part regarding routing, scheduling and contingency planning.

Routing

With the selected transport mode, this subpart will further study how it operates. Based on the locations of the industrial zones in the region of Ba Ria-Vung Tau, Dong Nai, Binh Duong and Hochiminh, the optimal route of LNG from the terminal to these end users can be drawn up hereto.

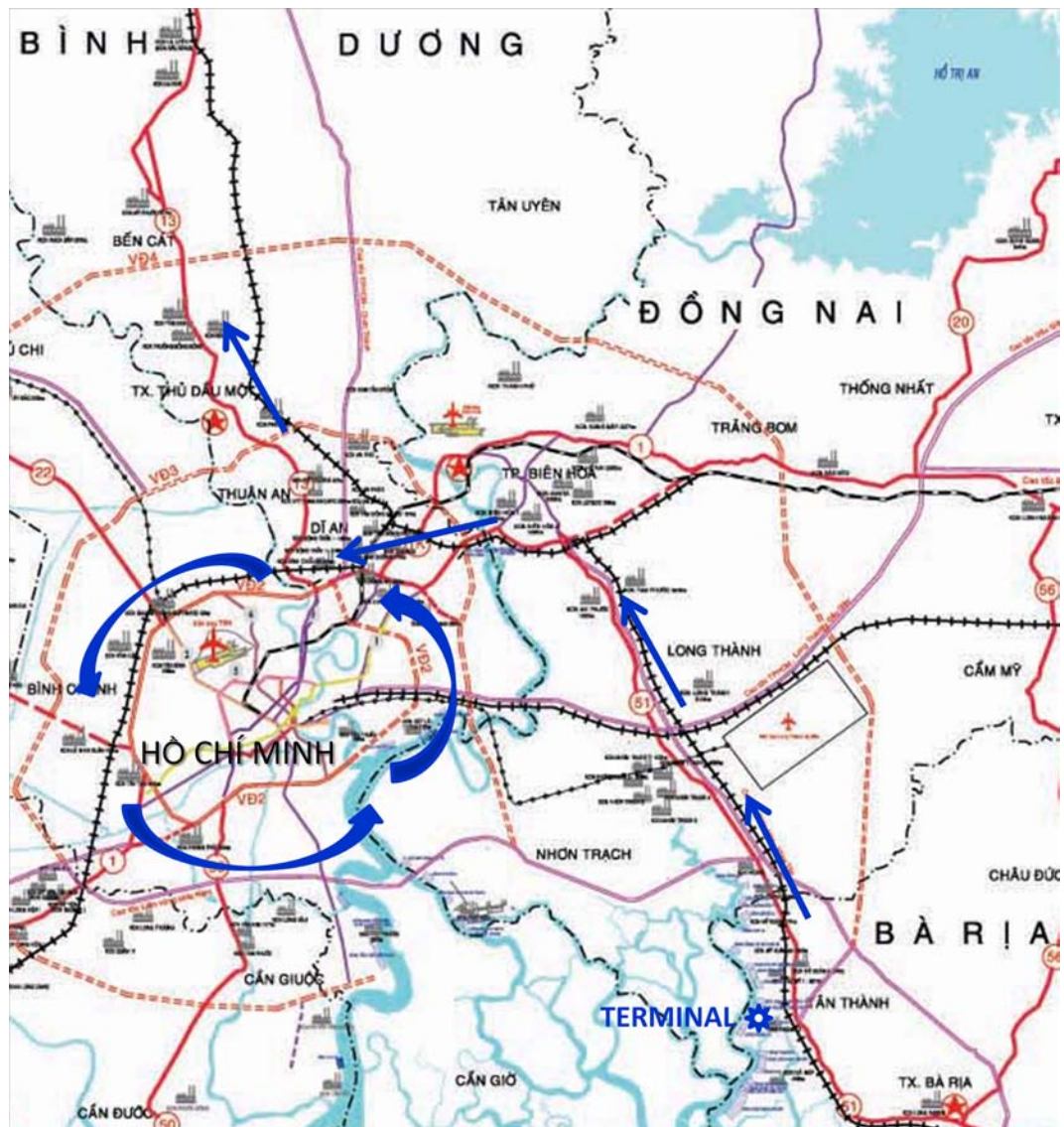


Figure 27 – LNG routing in Ba Ria-Vung Tau province, Dong Nai province, Binh Duong province and Hochiminh city

(map: Department of Transportation Ba Ria-Vung Tau 2008.)

As revealed by the figure, the transport route of LNG is along highways (in red). The industrial zones in Ba Ria-Vung Tau are sited near the terminal and next to Highway 51, thus, can be reached by either provincial roads or the highway. From Ba Ria-Vung Tau to Dong Nai, road tankers go on Highway 51. If the end user is in Dong Nai, they will reach there by turning right to Dong Nai provincial roads. Otherwise, road tankers turn left going on Hanoi Road to enter Binh Duong or Hochiminh. As can be seen, to Binh Duong, road tankers after leaving Hanoi Road, go up north along Highway 13. Most industrial zones in Binh Duong are right next to the highway, hence, convenient to reach. On the other hand, to Hochiminh city, road tankers get on Boundary Highway 2 which surrounds the city. This is due to both the restriction of trucks from entering the city centre and locations along this boundary highway of most city industrial zones.

Scheduling

In case that LNG is transported to end users in Ba Ria-Vung Tau or Dong Nai, the schedule can be arbitrary or dependent on users' requests. Conversely, schedules of transportation to Binh Duong and Hochiminh are limited to certain time. It is the case that there are frequent traffic jams at cross roads on Hanoi Road in rush hours. This is due to the excessive traffic volume on Hanoi Road which is a key regional corridor. On one hand, this occurs when citizens go to work in the morning or back home in the afternoon. As a result, the convenient time for truck transportation is 9 a.m.–4 p.m. and after 9 p.m. On the other hand, the constrained amount of time for truck transportation leads to the overload on the highway at about 9 a.m. and 9 p.m. when many trucks strive to enter Hochiminh city. For this reason, it is suggested that road tankers to Hochiminh and Binh Duong arrive at Hanoi Road at 11 a.m.–3 p.m. or after 11 p.m. From the terminal location to Hochiminh or Binh Duong, it takes roughly an hour and a half, which implies that the road tankers may depart from the terminal at 9.30 a.m.–1.30 p.m. or after 9.30 p.m.

Other than delivery time, the number of road tankers to end users is also necessary to be taken into consideration. Hereto is the formula for number of road tankers:

$$\begin{aligned} &\text{Number of road tankers (number of vessels) to an end user per day} \\ &= \text{end user's demand per day} / \text{capacity of vessel} \\ &= \text{end user's demand (ton)} / 16.5 \text{ (ton)} \end{aligned}$$

Since smooth operations of an industrial end user seriously depend on continuous supply of LNG, it is important to ensure this with the view of peak demand or terminal shutdown. Supply can be made available in peak demand season by erratic schedules or buffer storage while in shutdown time by only buffer storage. Based on experiences, terminal shutdown usually takes 3 to 4 weeks. Therefore to ensure supply in a continuous and constant manner, it is advisable to have 4 weeks of LNG buffer. It is proposed that 2 buffer weeks can be ensured by cryogenic vessels at end user locations and another 2 buffer weeks by LNG storage tanks at the terminal. Accordingly, we can determine the number of buffer vessels at end user locations:

$$\begin{aligned} &\text{Number of buffer vessels at an end user location} \\ &= \text{number of vessels delivered per day} * \text{number of buffer days} \\ &= \text{number of vessels delivered per day} * 14 \end{aligned}$$

Contingency planning

Furthermore, for a contingency plan, a number of contingency vessels which equals to 1/5 of the number of buffer vessels would be made available at end user locations. Thus, we have the formula for the number of contingency vessels at end user locations:

$$\begin{aligned} &\text{Number of contingency vessels at an end user location} \\ &= \text{number of buffer vessels at an end user location} / 5 \\ &= (\text{number of vessels delivered per day} * 14) / 5 \\ &= \text{number of vessels delivered per day} * 2.8 \end{aligned}$$

To sum up briefly, total vessels include delivered vessels, buffer vessels and contingency vessels.

6.2 Transportation to power plants

In accordance with the plan, the price that EVN is willing to pay for gas will be gradually adjusted to reach the level that is profitable for the LNG project. At that time, imported LNG can be sold to power plants. Hence, besides transportation to industrial zones as usual, LNG is transported to its main target customers – power plants.

6.2.1 Transport mode

As revised in the theoretical part, a pipeline is especially and only suitable for liquid products such as gas. A pipeline acts a role of not only a carrier but also infrastructure for transportation. A primary prerequisite of a Natural Gas pipeline system is capability of meeting peak demand. In account of this, LNG peaking facilities are developed along with direct transmission from upstream. In the transportation to industrial zones, the utilised mode is not pipeline but roadway due to the small volume and high fixed costs of pipeline. On the contrary, with the large volume, pipeline is the optimal choice as a transport mode due to its low variable costs.

With the use of a pipeline, LNG is regasified at the terminal and transmitted in gaseous form. In many places, a Natural Gas pipeline system is principally configured for long-distance transmission from production areas to market areas. The long-distance pipelines are commonly known as trunklines. At the other extreme, a grid pipeline system distributes Natural Gas to end user locations. This grid system may receive Natural Gas from the major trunklines or directly from production areas. The design of a pipeline system involves possible combinations of pipe sizes, compression equipments and inter-station distances to find out a solution that maximize efficiency and minimize transportation costs. (EIA 2009a.)

To calculate the volume of Natural Gas carried in the pipeline, there are a range of factors, among which the most important ones are the diameter of the pipe and its operating pressure. In practice, the pipeline design standard states that all pipelines going through populated areas need to decrease its maximum operating pressure for safety. It is common to keep the nominal pipe diameter but increase wall thickness with a view to maintaining constant pressure along the line. Wall thickness increase allows withstand of greater pressure to ensure safety criteria. (EIA 2009a.)

In overall, pipeline system configuration should satisfy a comparatively low load factor (usage level) in low demand season but a much higher load factor in peak demand season for grid pipeline system. Instead, the trunkline should maintain operating at a sustained high load factor all year round. (EIA 2009a.)

6.2.2 Operations

Regardless of the advantages of a pipeline to gas transmission, establishment of a pipeline system, in most cases, is hindered by control station construction and rights of way. As demonstrated by the title, we are going to examine the operational plan of the Natural Gas pipeline system from the LNG receiving terminal to nearby power plants, in terms of distribution centre establishing/ selecting and routing.

Distribution centre establishing/ selecting

A complete gas transmission system usually includes processing plants and distribution centres. In the region, there is Dinh Co gas processing plant. Here, the operation is to extract Natural Gas liquids and impurities from the Natural Gas stream. In other words, it produces pipeline quality Natural Gas. Besides, there is Phu My DC which is a regional gas distribution centre, sited in the location of Phu My power plant. Due to a variety of gas sources, Phu My DC carries out functions as a station where gas transmission is regulated in terms of schedule, volume and property. This is made in accordance with each user's transmission contract and request. Demand information from end users is collected by the regulator headquarter who processes and passes it to regional distribution centres, such as Phu My DC. With these data, Phu My DC calculates to figure out the most preferred solution, as a result, optimizes efficiency and minimizes costs.

In this LNG project, the purchase activities and terminal processing operations can ensure the quality of Natural Gas, which implies no necessary processing plant. Unlike a processing plant, a distribution centre in this case is of significant importance. Otherwise, the terminal cannot solely manage distributing to end users with the right amount and right property of gas. In the region, so far, there is only Phu My DC. It is the fact that building up a new distribution centre costs time and money and Phu My DC locates not far from the terminal. Taken this into account, the pipeline from the LNG terminal should utilise Phu My DC for reinforcement. Not limited to these reasons, it is also because from Phu My DC to the regional power plants, the proximity is close. The regional power plants (PPs) mentioned here are Ba Ria PP, Phu My PP, Nhon Trach PP, Hiep Phuoc PP and Thu Duc PP, which are illustrated in the following map.



Figure 28 – Southeast Vietnam gas pipeline infrastructure – current and under construction

Routing

In practice, many transmission pipeline routes belong to the “looped” category. Looping is when one pipeline is constructed and laid parallel to another, which is a solution to increase capacity along a right-of-way of only one line or expand existing pipeline infrastructures. Some very large pipeline system can have 5 or 6 parallel lines along a right-of-way. Looping can be applied to a long distance or a short portion of the line. With this solution, the costs of construction, in which land preparation is significant, can be seriously reduced while deliveries to consumers during peak periods can be ensured. (EIA 2009b.)

As can be seen in the figure above, there are under-construction pipeline infrastructures connecting Phu My PP and Nhon Trach PP, Hiep Phuoc PP, Thu Duc PP. In addition, Phu My DC is right at Phu My PP location. Together, these result in that the optimal route is along the route under construction, thus, making use of the right-of-way. To summarise, the pipeline system from the terminal to the power plants is constructed from the terminal to Phu My, then along the route of another pipeline under construction (as in the map) to reach Nhon Trach, Hiep Phuoc and Thu Duc. It is supposed not to deliver Natural Gas from the terminal to Ba Ria PP. The reason is that Ba Ria PP is located nearest to the upstream, thus already supplied with a sufficient amount.

7 COST AND PERFORMANCE MEASUREMENT

So far, we have developed a transport system of LNG. Nevertheless, it is not all: a system cannot go smoothly without appropriate performance management. As far as we know, a system performance is constituted by performance of a wide range of component activities. Thus, to improve system performance is to improve component performance. Herein, an activity analysis framework is conducted in order to study costs and performance of component activities of the transport system. By better understanding activities, performance can be efficiently and economically enhanced. An activity analysis, which is provided in subheading 3.7, is now carried out as follows.

Activity analysis

Step 1: Defining the area of analysis

The activity analysis is applied to the transport system of LNG once it is transferred to PV Gas's supervision. This transport system, depending on the contract terms, can either comprise of voyage from port of shipment to port of destination or not. In this activity analysis, area of analysis is the transportation of LNG from the port of shipment in selling countries to the end users in Vietnam. The voyage from port of shipment to the receiving terminal is included as the shipping is partly involved in and affects the transport system in Vietnam.

Step 2: Defining the units of analysis

The analysis is conducted for LNG transportation to different groups of customers. The figure below gives a diagram illustrating units under activity analysis.

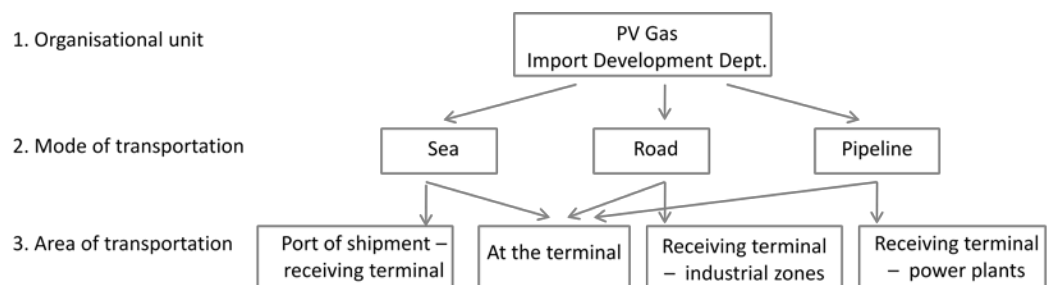


Figure 29 – Units of activity analysis

As revealed by the figure, there are two groups of customers – industrial zones and power plants. The transportation to these two groups both undergo voyage of port of shipment to the LNG receiving terminal and process at the terminal. The transportation modes are sea, road and pipeline respectively for transportation from port of shipment to the receiving terminal, from this terminal to industrial zones and from this terminal to power plants. All these units are under control of Import Development Department of PV Gas.

Step 3: Defining the activities

As explained, all components activities are necessary to be identified in order to enhance the whole transport system performance. These activities include establishing infrastructures, purchasing equipments, paying labour costs, administrating and handling products and services. A more detailed list of activities will be stated later on.

Step 4: Rationalizing activities

The table under the heading of transport costs demonstrates that each activity has its own associated costs. Therefore, activities do not only contribute to the whole transport system performance but also accumulate the total transport cost. Without conduct of an activity analysis, each component activity as well as order of the activities is not controlled. Then, this will lead to a chain effect that the inefficiency of the whole transport system is the result of a range of inefficient component activities. To improve the system, amendments must be carried out with each activity in particular and the system in general.

Step 5: Classification of activities, primary and secondary activities

According to the relevance to the focus of the thesis, primary and secondary activities are identified. Activities involving construction of terminals, utilisation of transport equipments, utilisation of channels and handling of the goods fall into primary category. Besides, purchase of equipments, human resource and organisational activities fall into secondary category, which support the primary activities.

Step 6: Preparation of activities

Since all activities are associated with its costs. Under this step, we have an overview of the related transport costs. In an LNG value chain as illustrated before, LNG shipping and receiving terminal activities constitute roughly half of the whole chain costs. The LNG shipping costs include capital costs, operating costs, voyage costs (bunker and channel fees). Although the average price of an LNG tanker is hard to determine, it is estimated to be nearly US\$ 225 million for a tanker of 145,000 m³. (EIA 2003b.) The figures below illustrate LNG costs, based on which shipping cost from various supply sources to Vietnam can be estimated.

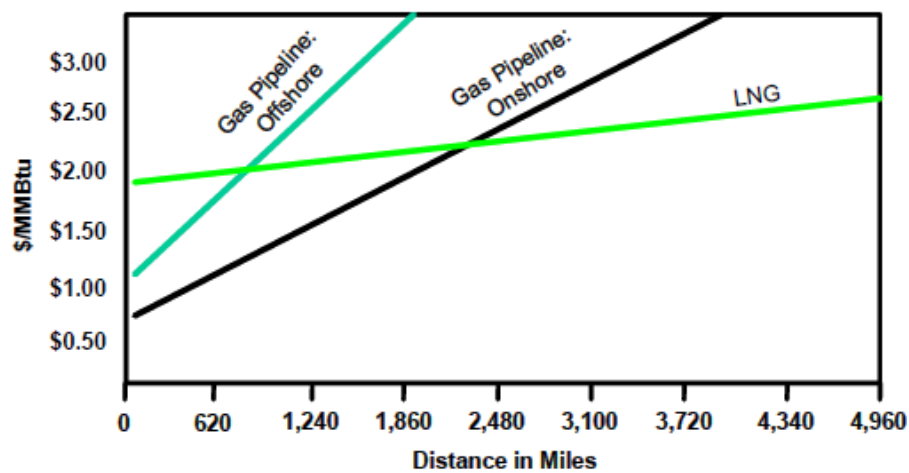


Figure 30 – LNG transport cost relative to distance (CEE 2007.)

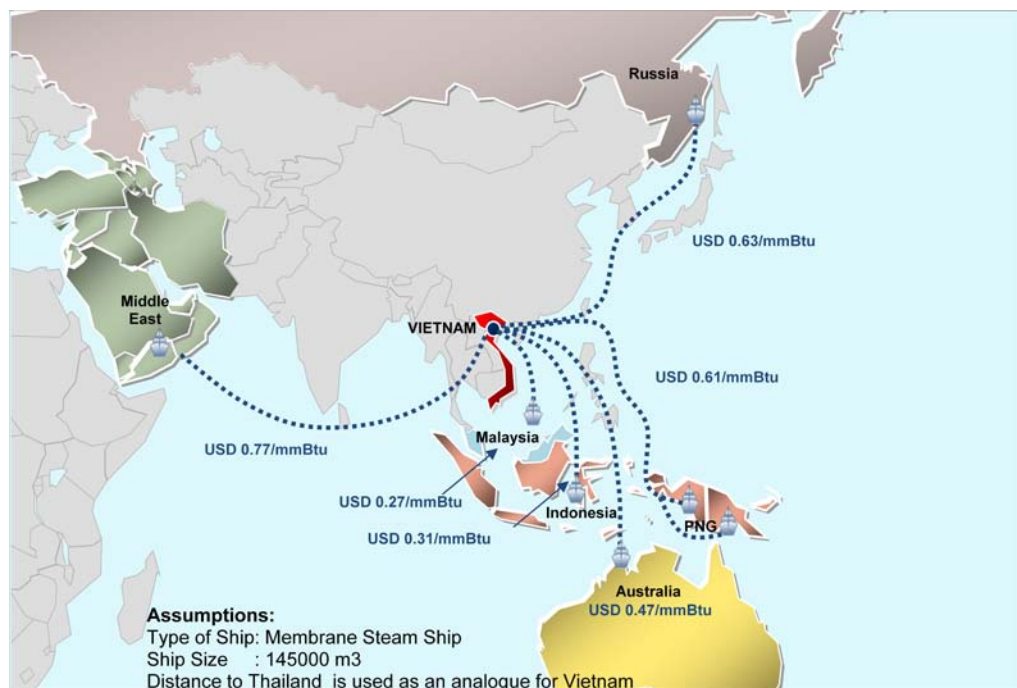


Figure 31 – Shipping cost from various LNG supply sources to Vietnam

Likewise, the costs of building receiving terminals show great variation and are site-specific. The terminal costs can vary from US\$ 100 million for a small terminal to US\$ 2 billion or even higher for a state-of-the-art terminal. The most costly unit in a terminal so far are the storage tanks. In most cases, dredging of access channel is needed for terminal operations and is a significant component cost of a receiving terminal. This could accumulate up to US\$ 100 million. The operational costs vary depending on cargo volume. (EIA 2003b.)

In the same manner, the costs of transportation by road tankers from the terminal to the industrial zones are variable. The costs principally vary due to changes in cargo volume in transit. There is no need for access channel maintenance since this cost is included in highway fee.

Conversely, the transportation costs of pipeline are almost fixed. This is due to the fixed infrastructures, carrier and routing on its own right of way. The most expensive costs are the fixed costs of constructing pipeline system. In some case, there might be more administration and maintenance needed due to unexpected incidence on pipeline system. Thus, the costs might slightly increase.

Step 7: Documentation of activities

Table 14 – Transport activity analysis

(table continues to next page)

Primary activity	Performance measurement	Secondary activity
1. Voyage from port of shipment to the LNG receiving terminal		
1. Tanker's voyage from port of shipment to the receiving terminal	1. Distance (km), duration (h), speed (km/h), ship capacity and utilisation (m ³), operating cost (US\$), bunker cost (US\$), canal toll & port due (US\$), ship delay (hour/day)	<ul style="list-style-type: none"> - Purchasing/building LNG tanker - Paying crew salaries and other fringe benefits - Paying insurance of damages and claims
2. Unloading at the terminal	2. Duration (h), unloading pump capacity (Bcf/billion ton), cost (US\$)	<ul style="list-style-type: none"> - Routing and scheduling - Planning of loading and unloading
3. Repairs and maintenance	3. Number per year (time), duration (day), cost (US\$)	<ul style="list-style-type: none"> - Administrating

2. At the LNG receiving terminal

1. Receiving terminal's establishment	1. Capacity (Bcf, billion ton), duration (month/ year), cost (US\$)	- Paying power costs - Paying labour costs and other fringe benefits
2. Access channel dredging	2. Length (m), number per year (time), cost (US\$)	- Scheduling
3. Receiving terminal's operations	3. Capacity & utilisation (Bcf/ billion ton), number of berths (unit), ship delay (number, hour/ day), handling length (h), cost (US\$)	- Planning of loading and unloading - Administrating
4. Repairs and maintenance	4. Number per year (time), duration (day), cost (US\$)	

3. Road transport from the LNG receiving terminal to the industrial zones

1. Loading to road tanker	1. Duration (h), pump capacity (Bcf/ billion ton), cost (US\$)	- Purchasing road tanker - Paying driver salaries and other fringe benefits
2. Road transportation	2. Distance (km), duration (h), speed (km/h), tanker capacity and utilisation (m ³), fuel cost (US\$), highway fee (US\$), delay (hour)	- Paying insurance of damages and claims
3. Unloading from road tanker	3. Duration (h), pump capacity (Bcf/ billion ton), cost (US\$)	- Routing and scheduling - Planning of loading and unloading
4. Repairs and maintenance	4. Number per year (time), duration (day), cost (US\$)	- Administrating

4. Pipeline transport from the LNG receiving terminal to the power plants

1. Regasification and pumping to pipeline system	1. Duration (h), pump capacity (Bcf/ billion ton), cost (US\$)	- Constructing pipeline - Paying insurance of damages and claims
2. Pumping from the terminal to end users	2. Distance, duration (h), pump capacity (Bcf/ billion ton), cost (US\$)	- Routing and scheduling
3. Regulating at distribution centre	3. Amount (Bcf), duration (h), cost (US\$)	- Administrating
4. Repairs and maintenance	4. Number per year (time), duration (day), cost (US\$)	

8 CONCLUSION

To finish off the thesis, a conclusion is stated in this chapter. The intent is to summarise the findings, analyse their implications and give recommendations for the LNG import project. The conclusion is presented under subheadings with respect to the role of LNG import, planning of LNG import and implementation of LNG import.

8.1 LNG import's role to the energy market of Vietnam

LNG is Natural Gas in liquid form which helps the transportation become more efficient and economic. Likewise to Natural Gas, it is used in a wide variety of fields, from household to industrial sector and power sector. The demand for LNG in Vietnam stresses the preference of LNG to other fuels.

LNG offers the opportunity to store Natural Gas and flexibly transport for peak demand while pipeline gas hardly meets this requirement. There is a visible trend towards environmental concerns while energy products and services are frequently sources of pollution. The nature of LNG makes itself a preferred energy for its environmental friendliness. LNG/ Natural Gas is considered the cleanest energy and to be the common choice for the near future.

Above all, the LNG technology has been to a great extent improved. This is reflected in a safety record where there are no deaths or serious accidents. It is a fact that LNG has been handled safely for many years. The global advance of the LNG technology is a reason for PV Gas to implement an LNG import project. In brief, importing LNG is a right decision for the energy market of Vietnam at the time being.

By contrast, there are risks associated with investment in LNG. As far as we know, LNG is emerging as a globally important energy. This implies that more and more countries are to depend on a certain number of supply sources. Thus, any unexpected problems arising in these supply countries will more or less affect the energy market of buying countries including Vietnam. As a result, considerations must be carefully taken in order to select and approach to reliable supply sources.

8.2 LNG import planning

With a view to make LNG an available and widely used energy in Vietnam, energy companies must invest in the LNG value chain. PV Gas, therefore, has initiated the LNG import project. The project is associated with enormous benefits but also with substantial difficulties in planning a feasible and economic transport system. To figure out solutions, thorough understanding of a transport system is crucial.

Owing to the nature of the transport modes, every transport mode has its own pros and cons. As a result, a considerable resolution is the combination of different transport modes. In this study, intermodal transportation model is applied. In light of nearly impossibility of constructing pipelines to transmit LNG to Vietnam from distant supply sources, the optimal option is sea-born LNG transportation using LNG tankers. To reach different types of end users, different modes of transportation are utilised. As illustrated, with small demand of industrial zones, road tankers are used and with large demand of power plants, pipelines are used.

The key node in the LNG transport system in Vietnam is the receiving terminal which links sea-born and onshore transportation. In practice, for establishing a receiving terminal, there are many options like shallow water or deepwater locations, onshore, near shore or deep offshore locations. This is according to marine environment, onshore conditions, available pipeline infrastructures, target market and general environmental forces. Statistical analyses and physical tests should be performed to find out the most preferred location for the LNG receiving terminal.

Offshore LNG import terminals may offer some advantages over onshore import terminals in the short term. On the contrary, onshore terminals tend to be of more economic sense in the long run. This fact is demonstrated by the findings of the thesis. Nonetheless, to evaluate the trade-offs, infrastructure and operational costs must be weighed. The principal rule is to select innovative and proven terminal designs and regasification technologies which are most suitable to the local conditions. Since the port location is endowed of rich resource of seawater, the sea-based vaporizer technology for LNG regasification is utilised.

The implementation of a transport system requires detailed and careful planning. To carry out the tasks, there should be cooperation among all related units. At the management level, the planning is conducted and assessed. The plan involves preparing infrastructures, routing, scheduling and contingency planning and other issues of relevance. This planning is handed over to executives for implementation and assessment. The assessment results subsequently are sent back to the management level for amendments and corrections. Moreover, the transport circumstances may regularly change, thus, prompt planning, implementation and feedback for improvement are obligatory.

8.3 LNG import implementation

The measurement and control of the LNG project is of great importance. The current estimate shows that the cost of full value chain has increased about 30% in comparison with what it was in 2002. The cost increase is a result of general energy cost increase all over the world. This is due to dramatically higher energy demand and more expensive supply input such as materials and skilled labours. Therefore, a cost-based activity analysis must be conducted to identify and correct malfunctions. Only with proper management, efficiency can be maximized and costs be minimized.

On the other hand, with improved technology, recent growth of LNG value chain costs has lessened. This fact noticeably indicates that besides measurement and control, research and development is the key to success. R&D activities can be conducted with a view of either adaptation to the local conditions or innovation in widely applied technologies.

To fully employ the advantages, the operations of LNG transportation must comply with the industry standards. These involve safety, air and water standards. In some countries, there are concerns about inherent hazards of LNG which are attractive to terrorists. It is the case that Vietnam is of stable politics, yet, assured security is a prerequisite. Also, more safety researches should be encouraged.

There is a time-sensitive window for PV Gas to implement the LNG import project to take the leading position in the LNG industry of Vietnam as well as meet the shortfall in the near future. Therefore, clear goals and schedules should

be set in details. Furthermore, though recommended to be as early as possible, the goals and schedules must be feasible to be carried out.

The loosened control of the government on energy prices in Vietnam is the chance for PV Gas and other energy players to venture into infrastructures and services related to LNG. It is recommended to put in practice more deregulation of the gas market in order that the market is competitive and thus beneficial. Furthermore, the government should have policy initiatives and fiscal incentives to encourage investment and commitment in LNG import activities.

Together, the government and industry should widely educate the public of the importance of LNG and building LNG import terminals. It is possible to establish and operate an LNG terminal with mostly all positive environmental profits provided that appropriate management and technologies are ensured. However, in all cases, the management board should be ready to interact with government or community concerns and accordingly alter the project.

Besides all the planning for the transportation, the purchase activities are also considerable. Though purchase is not included in the transportation, it directly affects the transport system. A significant issue is contract terms stating contract length and parties' responsibilities. The contract terms to a great extent affect the infrastructures and operations of the transport system in Vietnam.

Last but not least, despite the great concentration and effort on the LNG import project, the domestic gas supply potential of Vietnam should not be ignored and underestimated.

9 SUMMARY

The study starts with the introduction of LNG which is the product under discussion. Prior to description of LNG, an overview of Natural Gas regarding its composition and usage is given. LNG is Liquefied Natural Gas. Once Natural Gas is liquefied, the volume is dramatically reduced about 600 times. For this reason, LNG is very useful, especially for transportation. The later subheading of this chapter summarises LNG properties and LNG value chain. An LNG value chain is defined as a four stage process – upstream and gas processing, liquefaction, shipping and regasification.

With the aim of analysing and developing a transport system, chapter 3 provides theories regarding a transport system. The theoretical part first and foremost introduces what a transport system is. Transportation is a critical part within a scope of a logistics system. Transportation performs two functions: product movement and product storage. A transport system is comprised of a variety of components which can be categorised as external components and internal components. External components are formed by stakeholders while internal components are infrastructures and operations.

Subsequently, the relationship between a transport system and geography is demonstrated. From a transport geography perspective, a transport system can be defined as a set of three concepts - nodes, networks and demand. These three are interlinked by locations, terminals and flows. The complex relationship between a transport system and the spatial structure can be identified at three focal scales: global, regional and local. For analysis purpose, a transport system can be represented by a transport network. In general, a transport network is a framework demonstrated with links and nodes. The utilised transport network in this case study is featured with modes and terminals.

Subheadings 3.3 and 3.4 study in-depth two components of the identified transport network. Firstly, transport modes are under discussion. Transport modes are means supporting mobility of products. There are five basic modes of transportation: rail, road, water, pipeline and air. Major characteristics of transport modes are speed, cost, reliability, door, packaging needs, risk of loss and damage, flexibility and environmental impact. Due to characteristics, each transport mode

has its own pros and cons. As a consequence, intermodal transportation arises as a solution to exploit different transport modes' pros and restrict their cons.

Secondly, a review of transport terminals is given. A terminal is a complex of infrastructures where cargo originates, terminates or is interchanged. Due to intermediate locations of some specific terminals, the terminal can accommodate more than one transport mode. Then, this terminal is called an intermodal terminal. Intermodal terminals include port terminals and distribution centres. Following this, criteria in selecting and constructing the intermodal terminals are displayed. Finally, transport terminal layouts are discussed.

With reference to transport operations, strategic plans and operational plans are concerned. A strategic approach performs planning of the whole transport system, whereas an operational approach conducts planning of the individual activities within the system. Two main operational activities are routing and scheduling.

Transport infrastructures and operations both accumulate costs. Five categories of transport costs are transport labour costs, transport equipment costs, transport organisation's costs, handling costs and channel costs. Owing to different characteristics, costs of transport modes differ from each other's.

Last but not least, two frameworks for transport system analysis are illustrated. A system analysis is performed to conclude a selection among alternatives. On the other hand, an activity analysis, with a view to performance improvement, is conducted to identify and reallocate costs among activities.

After a review of the product and transport system issues, a case study of Import Development Department of PV Gas is carried out. Focusing on the last stage of the value chain, the case study focuses on the transport system of LNG in Vietnam. The study discusses the transportation via the LNG receiving terminal to the end users in Vietnam.

Prior to analysis of the transport system, the current situation is emphasized. The situation analysis indicates the reasons and benefits of the LNG import project. Moreover, the analysis briefly explains external components of the transport system. The context is described from perspectives of micro environment and macro environment. Stakeholders in microenvironment are customers,

competitors and suppliers. In macro environment, related factors are politics, economics, society and technologies. This macro environment analysis can be referred as a PEST analysis. Lastly, a SWOT analysis is conducted to summarise the findings of the situation analysis.

A general overview of design data of an LNG receiving terminal is made. With the purpose to select the most preferred location for constructing an LNG receiving terminal, a system analysis is conducted. In this analysis, six proposed locations for sitting LNG terminal are abstracted into the framework. The framework is applied with the site selection criteria including port size, shelter afforded, natural conditions, channel access, channel depth, transportation infrastructure, communication, staffing, construction, resource supply and maintenance. All these criteria are given weighting factors and predicted in accordance with each proposed location. Based on the predicted performance and economic validation, among six proposed ports, Saigon New Port appears as the optimal site for building up an LNG receiving terminal in Vietnam.

With the identified location, a layout is needed to complete the terminal establishment. By reasoning, it is proposed to use two models of LNG terminals in different stages of the project. In the first stage, floating LNG terminals are utilised and in the latter stage, onshore LNG terminals utilised. In general, these two types of models share a lot in common in terms of regasification technologies. Taking the local conditions into consideration, the seawater-based technology is applied for the terminal. However, these two types of terminals as well show differences. A floating LNG terminal can be considered a ‘ready-to-use’ as it is an LNG tanker attached with operational facilities. Instead, an onshore LNG terminal occupies more spaces and consists of a complex of fixed facilities.

Once establishment of the terminal is completed, operations are to be planned. In regard to this, some main issues are discussed such as supply and shipping contract, storage and sendout capacity, and scheduling of LNG receipt and sendout.

The establishment of the terminal assists the development of transportation via the terminal to the end users. In chapter 6, transport modes and links from the terminal to the end users are under study. The target customers fall into two

categories: industrial zones and power plants. For industrial zones, road transportation is used with means of road tankers. Road tankers are assumed to reach the end users in Ba Ria-Vung Tau, Dong Nai, Binh Duong and Hochiminh. An operational plan is developed with relation to routing, scheduling and contingency planning. The regional in-place highways are utilised. According to demand and traffic, scheduling and contingency planning are analysed.

For power plants, a pipeline is used with the view of large volume of LNG in transit. Target power plants (PPs) in nearby regions include Phu My PP, Nhon Trach PP, Hiep Phuoc PP and Thu Duc PP. As to this transport mode, operations planning mainly involves distribution centre establishing/ selecting and routing. Phu My DC is identified as a facility in the pipeline system to the power plants. Besides, the pipeline system makes use of the right-of-way of another pipeline which also aims to supply gas to the target power plants.

To ensure an efficient transport system, performance measurement must be performed in combination with planning and implementing. An activity analysis framework is applied to the case study. The analysis identifies and classifies the related activities into primary and secondary categories, then accordingly documents them with the performance measures. By undertaking this activity analysis, costs are identified, accordingly diminished or reallocated to right activities.

REFERENCES

Published references

Axinn, W.G. & Pearce, L.D., 2006, *Mixed Method Data Collection Strategies: Strategies*, Illustrated edition, Cambridge University Press

Bowersox, D.J., Closs, D.J. & Cooper, M.B., 2010, *Supply Chain Logistics Management*, 3rd edition, The McGraw-Hill Companies, Inc., Singapore

Branch, A. E., 2007, *Elements of shipping*, 8th edition, Taylor & Francis

Comtois, C., Rodrigue J-P. & Slack, B., 2009a, *The Geography of Transport Systems*, 2nd edition, Routledge, Wiltshire

Cooper, D.R. & Schindler, P.S., 2008, *Business Research Methods*, International edition, McGraw-Hill Irwin

Creswell, J.W., 2003, *Research Design: Qualitative, Quantitative, and Mixed Method Approaches*, 2nd illustrated, annotated edition, SAGE Publications Ltd

Ellram, L., Lambert, D. & Stock, J., 1998, *Fundamentals of Logistics Management*, Irwin/McGraw-Hill Companies, Boston

Gourdin, K.N., 2001, *Global logistics management: a competitive advantage for the new millennium*, Blackwell Publishers Ltd, Oxford

Kotler, P. & Armstrong, G., 2004, *Principles of Marketing*, 10th edition, Pearson Education Inc., New Jersey

Kumar, R., 2005, *Research Methodology: A Step-by-step Guide for Beginners*, 2nd edition, SAGE Publications Ltd

Mertens, D.M., 2004, *Research and evaluation in education and psychology: integrating diversity with quantitative, qualitative, and mixed methods*, 2nd revised edition, SAGE Publications Ltd

Oksanen, R., 2003, *Application and implementation of activity-based costing of transportations (Kuljetusten toimintolaskennan sovellukset ja toteutus)*,

Publications of the Ministry of Transport and Communications 17/2003, Oyj Edita Abp, Helsinki, (translated by Ravantti, Hede)

Oksanen, R., 2004, Activity-based costing of transportations (Kuljestustuotannon toimintolaskelma, kuljestalouden perusterista moderniin toimintolaskelmaan), Aaltospaino Oy, Tampere, (translated by Ravantti, Hede)

Padgett, D. K., 1998, Qualitative methods in social work research: challenges and rewards, Thousand Oaks: Sage

Sangeeta, S., 1999, An LNG project in India: Setting up of an import terminal and the role of transportation - A dissertation submitted to the World Maritime University in partial fulfilment of the requirements for the award of the degree of Master of Science in Shipping Management

Saunders, M., Lewis, P. & Thronhill, T., 2003, Research methods for business students, 3rd edition, Prentice Hall

Sussman, J., 2000, Introduction to transportation system, Artech House Inc., Norwood

Thoresen, C. A., 2003, Port designer's handbook: recommendations and guidelines, illustrated/reprint edition, Thomas Telford

Waller, D. L., 2003, Operations management: a supply chain approach, 2nd edition, Thomson Learning, London

Electronic references

Ba Ria-Vung Tau Official Website, 2003a (accessed 2 August 2009), Natural conditions
http://www.baria-vungtau.gov.vn/zW00000003F/W00000003F_000001EAB.asp

Ba Ria-Vung Tau Official Website, 2003b (accessed 2 August 2009), Seaport potentiality
http://www.baria-vungtau.gov.vn/zW00000003F/W00000003F_000001EC7.asp

Ba Ria-Vung Tau Official Website, 2003c (accessed 2 August 2009), Education
http://www.baria-vungtau.gov.vn/zW00000001A/W00000001A_000001A16.asp

Ba Ria-Vung Tau Official Website, 2003d (accessed 4 August 2009),
Development potentiality
http://www.baria-vungtau.gov.vn/zW00000003F/W00000003F_000001EC7.asp

Canaport LNG, 2009 (accessed 6 August 2009), LNG: Ship to shore
http://www.canaportlng.com/pdfs/ship_to_shore.pdf

CEE (Center for Energy Economics), November 7, 2006 (accessed 5 August 2009), Offshore LNG receiving terminals
http://www.beg.utexas.edu/energyecon/lng/documents/CEE_offshore_LNG.pdf

CEE (Center for Energy Economics) January 2007 (accessed 22 August 2009),
Introduction to LNG
http://www.beg.utexas.edu/energyecon/lng/documents/CEE_INTRODUCTION_TO_LNG_FINAL.pdf

Comtois, C., Rodrigue J-P. & Slack, B., 2009b (accessed 9 July 2009), The
Geography of Transport Systems (e-book version), Chapter 1, Concept 1, The
transport system
<http://people.hofstra.edu/geotrans/eng/ch1en/conc1en/trspsystem.html>

Comtois, C., Rodrigue J-P. & Slack, B., 2009c (accessed 10 July 2009), The
Geography of Transport Systems (e-book version), Chapter 2, Concept 3, Scales
of spatial organization
http://people.hofstra.edu/geotrans/eng/ch7en/conc7en/table_scaleorganization.html
1

Comtois, C., Rodrigue J-P. & Slack, B., 2009d (accessed 11 July 2009), The
Geography of Transport Systems (e-book version), Chapter 3, Concept 6, The
nature of intermodalism
<http://people.hofstra.edu/geotrans/eng/ch3en/conc3en/ch3c5en.html>

Comtois, C., Rodrigue J-P. & Slack, B., 2009e (accessed 13 July 2009), The
Geography of Transport Systems (e-book version), Chapter 4, Concept 1
<http://people.hofstra.edu/geotrans/eng/ch4en/conc4en/ch4c1en.html>

Comtois, C., Rodrigue J-P. & Slack, B., 2009f (accessed 15 July 2009), The Geography of Transport Systems (e-book version), Chapter 4, Concept 3, Ports and port sites

<http://people.hofstra.edu/geotrans/eng/ch4en/conc4en/ch4c3en.html>

Comtois, C., Rodrigue J-P. & Slack, B., 2009g (accessed 17 July 2009), The Geography of Transport Systems (e-book version), Chapter 2, Method 2

http://people.hofstra.edu/geotrans/eng/ch2en/meth2en/ch2m2en_2ed.html

Department of Transportation Ba Ria-Vung Tau, 2008 (accessed 13 August 2009), Road traffic planning in south economic zone to 2020

<http://sogtvt.baria-vungtau.gov.vn/?opt=newsgroup&gr=4&idSub=9&id=51>

EIA (Energy Information Administration), December 2001 (accessed 8 August 2009), U.S. Natural Gas markets: mid-term prospects for natural gas supply

<http://www.eia.doe.gov/oiaf/servicerpt/natgas/chapter3.html>

EIA (Energy Information Administration), December 2003a (accessed 23 August 2009), The global LNG market, status and outlook, World LNG market structure

<http://www.eia.doe.gov/oiaf/analysispaper/global/lngmarket.html>

EIA (Energy Information Administration), December 2003b (accessed 23 August 2009), The global LNG market, status and outlook, LNG industry costs

<http://www.eia.doe.gov/oiaf/analysispaper/global/lngindustry.html>

EIA (Energy Information Administration), 2009a (accessed 18 August 2009), Network configuration and system design

http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/transsys_design.html#domestic

EIA (Energy Information Administration), 2009b (accessed 19 August 2009), Transport process and flow

http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/process.html

EVN, 2007 (accessed 23 June 2009), Power Development Plan VI

<http://www.evn.com.vn/Cáctrangân/Quihoachdien6/tabid/78/language/vi-VN/Default.aspx>

GIIGNL, 2009 (accessed 19 June 2009), What is LNG?

<http://www.giignl.org/index.php?id=6>

Gorgon Project, Chevron, 2009 (accessed 19 June 2009), The Gorgon project, Fact sheets, What is LNG?

<http://www.gorgon.com.au/06-news/factsheets/Gorgon%20Fact%20Sheet%20-%20What%20is%20LNG.pdf>

Hai Phong Official Website, 2003a (accessed 2 August 2009), Natural conditions

http://www.haiphong.gov.vn/en/front-end/index.asp?website_id=39&menu_id=350&parent_menu_id=348&fuseaction=DISPLAY_ALL_ARTICLE_BY_MENU

Hai Phong Official Website, 2003b (accessed 2 August 2009), Summary on the adjustment to the overall master plan for Haiphong city to the year 2020

http://www.haiphong.gov.vn/en/front-end/index.asp?website_id=39&menu_id=358&parent_menu_id=348&article_id=869&fuseaction=DISPLAY_SINGLE_ARTICLE

Hai Phong Official Website, 2003c (accessed 2 August 2009), Investment incentives

http://www.haiphong.gov.vn/en/front-end/index.asp?website_id=39&menu_id=341&parent_menu_id=338&article_id=809&fuseaction=DISPLAY_SINGLE_ARTICLE

Hai Phong Official Website, 2003d (accessed 4 August 2009), IZs and EPZs in Haiphong

http://www.haiphong.gov.vn/en/front-end/index.asp?website_id=39&menu_id=343&parent_menu_id=356&fuseaction=DISPLAY_ALL_ARTICLE_BY_MENU

International Gas Union, 2003a (accessed 1 June 2009), 22nd World Gas Conference, WOC reports, WOC 3 report: Liquefied gases, Part 1

http://www.igu.org/html/wgc2003/WGC_pdffiles/WOC_R_3.pdf

International Gas Union, 2003b (accessed 1 June 2009), 22nd World Gas Conference, WOC reports, WOC 7 report: Industrial Utilisation and Power Generation

http://www.igu.org/html/wgc2003/WGC_pdffiles/WOC_R_7.pdf

International Gas Union, 2006a (accessed 2 June 2009), 23rd World Gas Conference, PGC D, Safety and technology developments in LNG plants, terminals and vessels: Report from study group D2

<http://www.igu.org/html/wgc2006pres/data/wgcppt/pdf/PGC%20Programme%20Committees/PGC%20D/Safety%20and%20technology%20developments%20in%20LNG%20plants,%20terminals%20and%20vessels/9.3EF.02.pdf>

International Gas Union, 2006b (accessed 3 June 2009), 23rd World Gas Conference, PGC D, LNG quality technological and economic aspects: Process for the adjustments of the HHV in the LNG plants, Total

<http://www.igu.org/html/wgc2006pres/data/wgcppt/pdf/PGC%20Programme%20Committees/PGC%20D/LNG%20quality%20technological%20and%20economic%20aspects/9.2EF.03.pdf>

International Gas Union, 2006c (accessed 3 June 2009), 23rd World Gas Conference, PGC D, Safety and technology developments in LNG plants, terminals and vessels: Management of large LNG hazards, Shell Global Solution

<http://www.igu.org/html/wgc2006pres/data/wgcppt/pdf/PGC%20Programme%20Committees/PGC%20D/Safety%20and%20technology%20developments%20in%20LNG%20plants,%20terminals%20and%20vessels/9.3EF.05.pdf>

Khanh Hoa Portal, 2003a (accessed 2 August 2009), Natural conditions

<http://www.khanhhoa.gov.vn/UBT/index.nsf/0/B4C7B22C9B95AEF4472571270007815A?Open&category=8143466D6A28B5B34725712900278458&id=8143466D6A28B5B34725712900278458&Start=0>

Khanh Hoa Portal, 2003b (accessed 2 August 2009), Economy potentiality

http://ws1.khanhhoa.gov.vn/ubt/indexe.nsf/FramMain_2?OpenFrameset&Frame=Framtarget&Src=http://ws1.khanhhoa.gov.vn/DataUbtE/2006-04-06-E2EE587AAB6CE6FC472571480004C1C5/potenciality.htm

Khanh Hoa Portal, 2003c (accessed 2 August 2009), Scope of encouraged investment and specific projects

http://ws1.khanhhoa.gov.vn/ubt/indexe.nsf/FramMain_2?OpenFrameset&Frame=Framtarget&Src=http://ws1.khanhhoa.gov.vn/DataUbtE/2006-04-07-2353B7A2C14E159A4725714800837D2F/SCOPE_OF_ENCOURAGED_INVESTMENT.htm

Maritech 2009 (accessed 1 August 2009), Map

<http://maritech.com.vn/map/saigon.html>

Mustang, 2005 (accessed 7 August 2009), Publications, LNG regasification terminal

<http://www.mustangeng.com/AboutMustang/Publications/Publications/LNG.pdf>

National Geospatial-Intelligence Agency, 8 August 2009, (accessed 10 August 2009) World Port Index, 18th edition, Vietnam ports

http://www.nga.mil/portal/site/maritime/index.jsp?epi-content=RAW&beanID=844643208&viewID=query_results&MSI_queryType=WorldPortIndex&MSI_generalFilterType=CountryCode&MSI_generalFilterValue=VM&MSI_additionalFilterType1=-999&MSI_additionalFilterType2=-999&MSI_additionalFilterValue1=-999&MSI_additionalFilterValue2=-999&MSI_outputOptionType1=-999&MSI_outputOptionType2=-999&MSI_outputOptionValue1=-999&MSI_outputOptionValue2=-999

NaturalGas.Org, 2004a (accessed 19 June 2009), Overview of Natural Gas, Background

<http://www.naturalgas.org/overview/background.asp>

NaturalGas.Org, 2004b (accessed 19 June 2009), Overview of Natural Gas, Uses

<http://www.naturalgas.org/overview/uses.asp>

NaturalGas.Org, 2004c (accessed 19 June 2009), Overview of Natural Gas, Focus on LNG

<http://www.naturalgas.org/lng/lng.asp>

OPEC, 2009 (accessed 9 June 2009), News, Price Volatility and Natural Gas Prospects, 9-12 March 2009

<http://www.opec.org/opecna/Speeches/2009/NGasDoha.htm>

Pegaz, 2009 (accessed 20 June 2009), About LNG, LNG value chain
<http://www.pegazlng.com/?id=93&LANG=EN>

PV Gas, 2009a (accessed 16 June 2009), PV Gas Introduction
<http://www.pvgas.com.vn:9081/wps/portal/GioiThieuEn>

PV Gas, 2009b (accessed 21 June 2009), PV Gas Organisational chart
http://www.pvgas.com.vn:9081/wps/portal/!ut/p/.cmd/cs/.ce/7_0_A/.s/7_0_1F7/_s.7_0_A/7_0_1F7?New_WCM_Context=http://intercontent.pvgas.com.vn:9081/wps/ilwwcm/connect/InternetEn/Introduction/Organization+Chart/

PNG LNG Project, ExxonMobil, 2008 (accessed 17 June 2009), Our commitment, Safety, Environment impact statement, part IV, Attachment 1: Properties and hazards of LNG
http://www.pnglng.com/media/pdfs/environment/eis_attachment01.pdf

Thanh Hoa Portal, 2007 (accessed 2 August 2009), General orientation
<http://www.thanhhoa.gov.vn/web/guest%20/dinhhuong>

The Word Factbook, July 2, 2009 (accessed July 22 2009), Vietnam
<https://www.cia.gov/library/publications/the-world-factbook/geos/vm.html>

Vietnam Industrial Parks, 2007 (accessed August 12, 2009), Industrial parks map
http://www.khucongngghiep.com.vn/IPmaps/ban_do_kcn.htm

Viet Law, 2005 (accessed July 20, 2009), Electricity law 28/2004/QH11
<http://www.luatvietnam.vn/Default.aspx?tabid=673&id=b6a68835-3b6d-4b97-be11-28fabd7406a3>

Vietnam Ministry of Industry, 2006a (accessed July 20, 2009), Document law, Establishment of Parent company – Vietnam Oil and Gas Group (PVN)
<http://www.moi.gov.vn/LDocument/Detail.asp?id=1846>

Vietnam Ministry of Industry, 2006b (accessed July 20, 2009), Document law, Establishment of Parent company – Vietnam Electricity (EVN)
<http://www.moi.gov.vn/LDocument/Detail.asp?id=1826>

Vietnam Ministry of Industry, 2006c (accessed July 20, 2009), Document law, Establishment of Parent company – Vietnam National Coal-Mineral Industries Group (Vinacomin)

<http://www.moi.gov.vn/EN/LDocument/Detail.asp?id=1925>

Vietnam Ministry of Industry, 2006d (accessed July 20, 2009), Document law, Establishment of Electricity Regulatory Authority of Vietnam (ERAV)

<http://www.moi.gov.vn/LDocument/Detail.asp?id=1685>

Vietnam Seaports Association, 2009 (accessed 1 August 2009), Capacities

http://www.vpa.org.vn/english/information/info_capa.htm

World Trade Ref, 2009 (accessed 30 July 2009), Ship illustrations

http://www.worldtraderef.com/WTR_site/cargo_vessels.asp

Interviews with PV Gas personnel

Name of interviewee	Position	Time of interview
Nguyen, Trung Dan	Vice president	July-August 2009
Vu, Hong Nga	Expert, Planning and Investment Division	

APPENDICES

Appendix 1 – List of interview questions

1. What are the benefits of importing LNG?
2. Who are potential customers and what is demand for LNG?
3. Who are potential LNG suppliers of PV Gas?
4. What are the constraints of the project? And what are PV Gas's suggested solutions?
5. Where (province, city) does PV Gas aim to locate the LNG terminal? What are reasons for these selections?
6. What are standards of the LNG carrier that PV Gas plans to utilise?
7. Which vaporizer technology does PV Gas plan to utilise? What are reasons for this selection?
8. What is the capacity of the road tanker for LNG transportation that PV Gas plans to utilise?
9. What is the role of Dinh Co gas treatment plant in the regional gas transmission?
10. What is the role of Phu My gas distribution centre in the regional gas transmission?

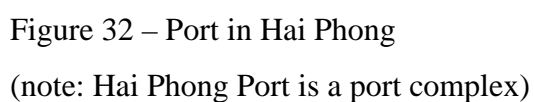




Figure 34 – Ports in Khanh Hoa

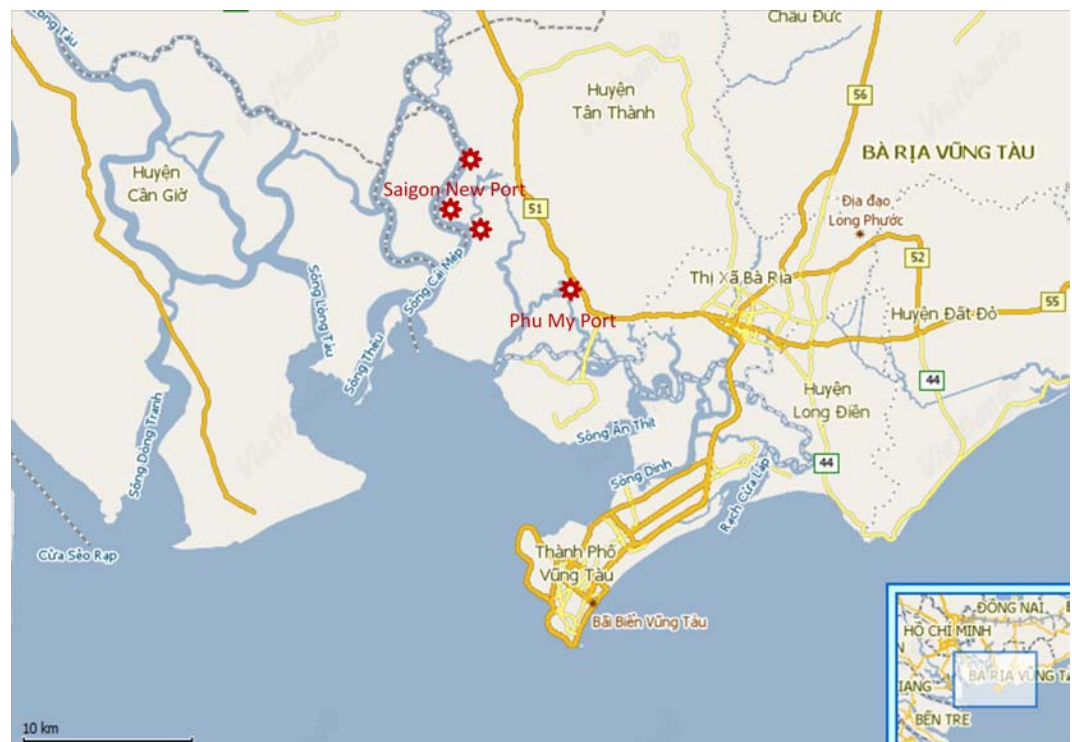


Figure 35 – Ports in Ba Ria-Vung Tau
(note: Saigon New Port is a port complex)

Appendix 3 – Preselected ports' index

Table 15 – Port index (National Geospatial-Intelligence Agency 2009 and Vietnam Seaports Association 2009.)

Port	Hai Phong	Thanh Hoa	Nha Trang	Cam Ranh	Phu My	Saigon New
Port size	M	V	S	S	V	M
Port type	RN	CN	OR	CN	RN	RN
Shelter afforded	E	F	F	G	F	E
Entrance restrictions:						
Tide	Y		Y	N		Y
Swell	N		Y	N		N
Other	Y	Y	Y	Y	Y	Y
Overhead limits	Y		N		Y	N
Channel depth	K	L	H	K	A	J
Max size vessel	L	M	M	L	M	L
Communications:						
Telephone	Y		Y		Y	Y
Telegraph			Y	Y	Y	
Radio	Y	Y	Y	Y	Y	Y
Radio tel.	Y	Y			Y	Y
Air	Y		Y	Y		Y
Rail	Y					Y
Supplies:						
Provisions	Y	Y	Y		Y	Y
Water	Y	Y	Y	Y	Y	Y
Fuel Oil	Y	Y	Y		Y	Y
Diesel Oil	Y	Y				Y
Deck	Y		N			Y
Engine	Y		N			Y
Repair	C		C			C
Drydock	S		L			S

General: Y=yes, N=no
 Port size: L-large, M-medium, S-small, V-very small
 Port type: CN-coastal natural, OR-open roadstead, RN-river natural
 Shelter afforded: E-excellent, F-fair, G-good, N-none, P-poor
 Max size vessel: L-over 500' length, M-up to 500' length
 Repair: A-major, B-moderate, C-limited, D-emergency only, N-none
 Drydock: L-large, M-medium, S-small
 Depth (meter): A 23.2-over, H 12.5-13.7, J 11.0-12.2, K 9.4-10.7, L 7.9-9.1

Appendix 4 – Calculating total scores of preselected ports

Table 16 – Total scores $\sum(F*S)$ and components scores (F*S) of preselected ports

Port	Hai Phong	Thanh Hoa	Nha Trang	Cam Ranh	Phu My	Saigon New
Port size	6	2	4	4	2	6
Shelter afforded	30	24	24	18	24	30
Natural conditions	6	2	4	16	12	9
Channel access	5	15	10	20	5	15
Channel depth	20	15	30	20	35	25
Transportation	30	15	25	20	25	30
Communication	30	18	24	24	24	30
Staffing	12	12	12	12	16	16
Construction	16	8	8	12	8	8
Resource supplies	36	30	24	24	36	36
Maintenance	2	3	3	2	1	3
Total	193	144	168	172	188	208

Appendix 5 – Conversion factors

Table 17 – NG and LNG conversion factors (CEE 2007, 38.)

Natural gas (NG) and LNG	billion cubic meters NG	billion cubic feet NG	million tons oil equivalent	million tons LNG	trillion British thermal units	million barrels equivalent (Boe)
From	Multiply by					
1 billion cubic meters NG	1	35.3	0.90	0.73	36	6.29
1 billion cubic feet NG	0.028	1	0.026	0.021	1.03	0.18
1 million tons oil equivalent	1.111	39.2	1	0.81	40.4	7.33
1 million tons LNG	1.38	48.7	1.23	1	52.0	8.68
1 trillion British thermal units (Btus)	0.028	0.98	0.025	0.02	1	0.17
1 million barrels oil equivalent (Boe)	0.16	5.61	0.14	0.12	5.8	1

Appendix 6 – Illustration of an LNG receiving terminal (Mustang 2005.)

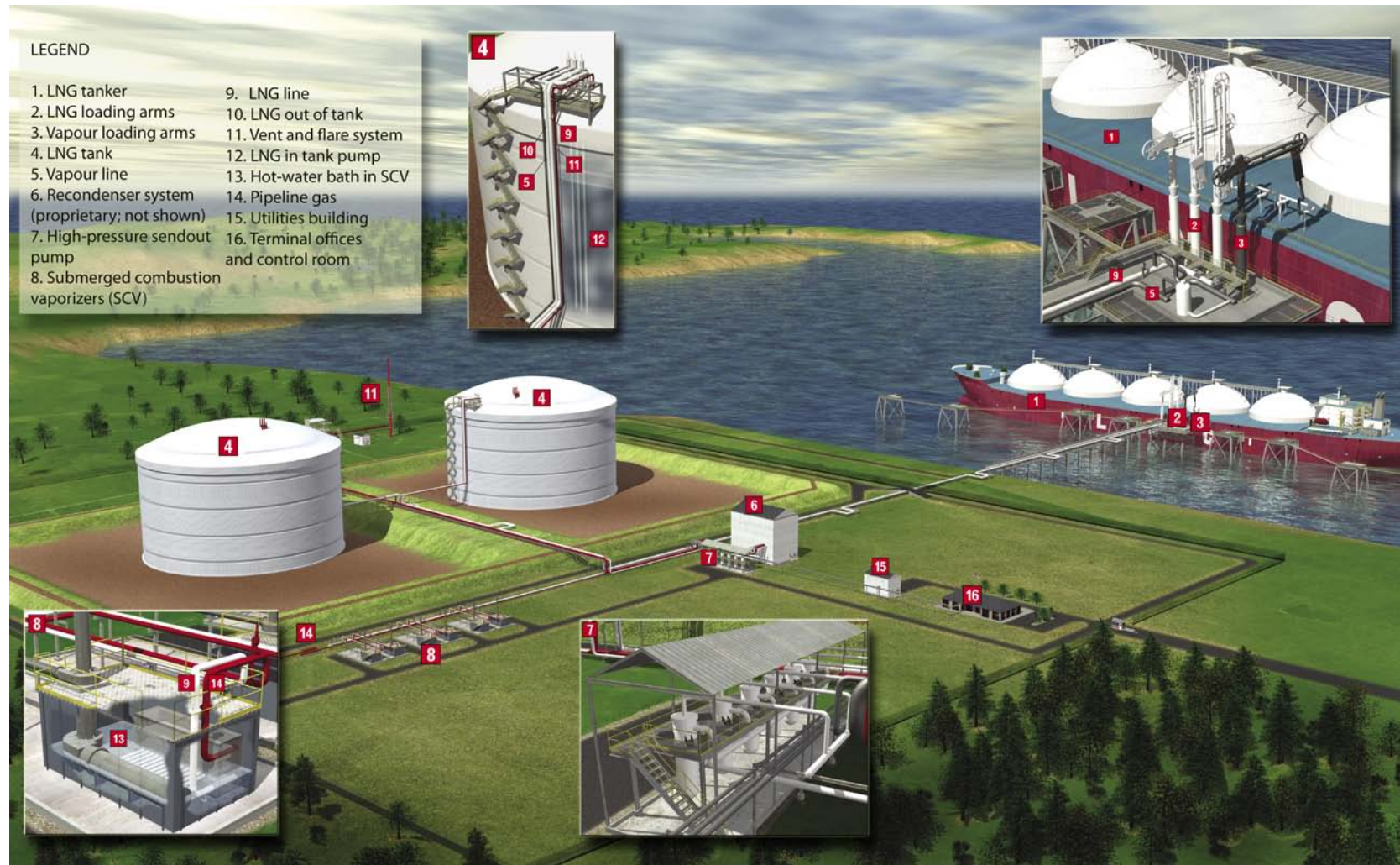


Figure 36 – Illustration of an LNG receiving terminal

Table 18 – Assumed LNG composition

*Assumed for the terminal illustrated. Designed of a particular LNG terminal may vary according to the composition of the LNG it is to receive.

LNG composition*	Mole %
Methane	96.44
Ethane	3.10
Propane	0.37
Nitrogen	0.02
i-Butane	0.04
n-Butane	0.03
i-Pentane	—
n-Pentane	—
Hexane+	—
Total	100.00
Molecular weight	16.61
LNG high heating value, btu/std. cu ft	1040.5
LNG low heating value, btu/std. cu ft	937.9

Appendix 7 – Industrial parks in the nearby region of the terminal

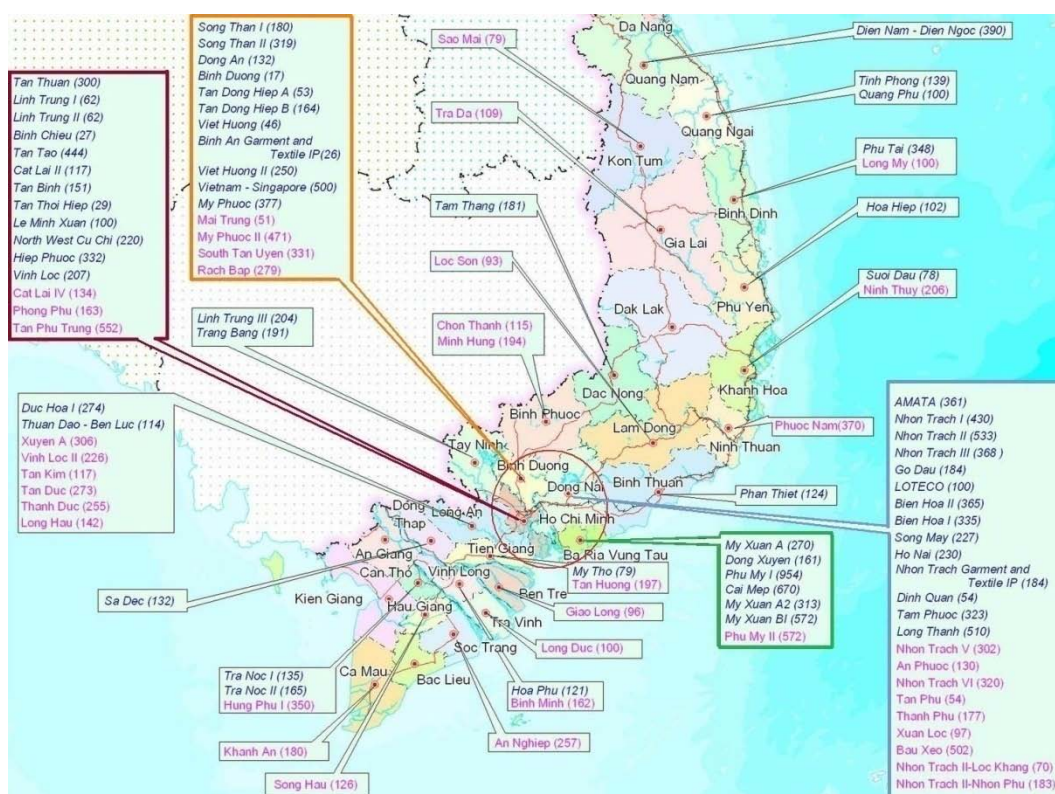


Figure 37 – Industrial parks in the region (Vietnam Industrial Parks 2007.)